United States
Environmental Protection
Agency

Solid Waste
and Emergency Response
Technology Innovation Office
Washington, DC 20460

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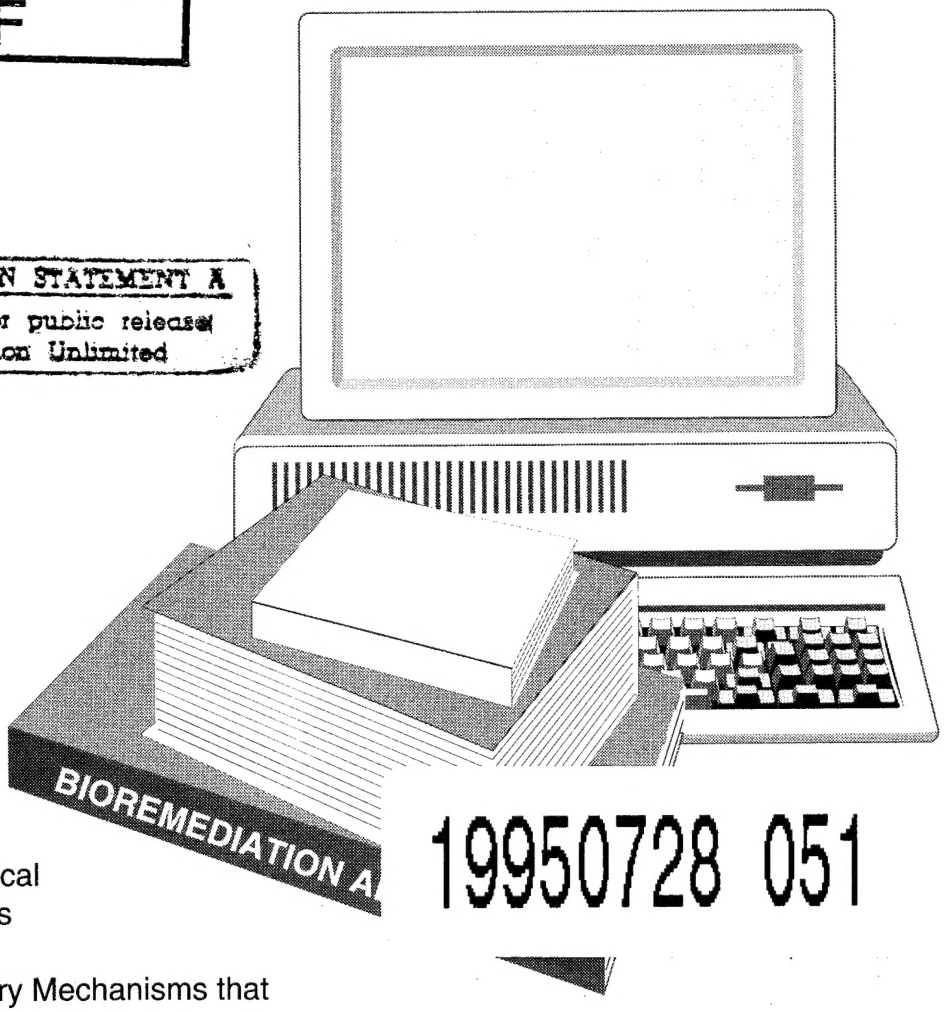
EPA Bioremediation Resource Guide



- Abstracts of Policy, Guidance, and Technical Assistance Documents
- Summary of Regulatory Mechanisms that Affect Bioremediation Technologies
- Descriptions of Bioremediation-Related Databases, Hotlines, Catalogs, and Dockets
- Easy to Use Matrix that Assists in Identification of Appropriate Documents

BIOREMEDIATION RESOURCE GUIDE and BIOREMEDIATION RESOURCE MATRIX

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office
Washington, DC 20460

September 1993

EXECUTIVE SUMMARY

This Bioremediation Resource Guide is intended to support decision-making by Regional and State Corrective Action permit writers, Remedial Project Managers (RPMs), On-Scene Coordinators, contractors, and others involved in evaluating cleanup alternatives for Resource Conservation and Recovery Act of 1976 (RCRA), Underground Storage Tank (UST), and Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) sites by directing readers to bioremediation resource documents, databases, hotlines, and dockets as well as identifying regulatory mechanisms (e.g., Research Development and Demonstration Permits) that have the potential to ease the implementation of bioremediation at hazardous waste sites.

This Guide provides abstracts of representative examples of over 80 bioremediation bibliographies, guidance, workshop reports, overview documents, study/test results, and test designs/protocols. The Bioremediation Resource Matrix, which accompanies this Guide, identifies the technology, media, and contaminants covered in each abstracted document. The included documents focus for the most part on soil and ground water and on in-situ, slurry phase, and land treatment bioremediation. Information contained in this Guide is not intended to be all-inclusive, nor does it represent an endorsement by the U.S. Environmental Protection Agency (EPA).

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INTRODUCTION

EPA is committed to identifying the most effective and efficient means of addressing the thousands of hazardous waste sites in the United States. Therefore, the Office of Solid Waste and Emergency Response's (OSWER's) Technology Innovation Office (TIO) at EPA is working in conjunction with the EPA Regions and research centers, and industry to identify and further the implementation of innovative treatment technologies. Currently, bioremediation is a frequently selected innovative technology.

The goal of OSWER is to encourage the development and use of innovative hazardous waste treatment technologies. One way of enhancing the use of these technologies is to ensure that decision-makers can avail themselves of the most current information on technologies, policies, and other sources of assistance. To this end, this Guide, which identifies documents that can directly assist RPMs and permit writers in investigating existing information on bioremediation remedial applications for contaminants usually found at RCRA, UST, and CERCLA sites, was prepared.

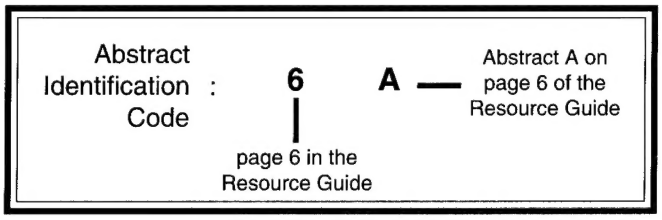
HOW TO USE THIS GUIDE

When using this Guide to identify resource information on bioremediation, you may wish to take the following steps:

1. Turn to the **Bioremediation Resource Matrix** located in the center of this Guide. This matrix lists over 80 bioremediation related documents and identifies the type of information provided by each document as well as a document ordering number.

2. Select the document(s) that appear to fit your needs based on the content information in the matrix.

3. Check the abstract identification code. This number refers to an abstract for the document. The number corresponds to a page number in the Guide and the letter corresponds to an abstract on that page. For example:



4. Review the abstract that corresponds to the document in which you are interested to confirm that the document will fit your needs.

5. If the document appears to be appropriate, check the document number highlighted under the abstract. For example:

EPA Document Number: 540/S-92/003

6. Turn to the section entitled "How to Order Documents Listed in this Guide" on page 3 of this Guide and order your document using the directions listed. You will find ordering forms identified in the section entitled "Order Forms," which begins on page 29 of this Guide.

7. When seeking information on technical assistance sources, turn to page 4 of this Guide.

8. To identify information on Federal regulations and guidance relevant to bioremediation, turn to page 5 of this Guide.

9. If you would like to comment on this Guide or would like additional information, turn to page 27 of this Guide and follow the directions for mailing or faxing your comments/questions.

HOW TO ORDER DOCUMENTS LISTED IN THIS GUIDE

Documents listed in this Guide are available through a variety of sources. When ordering documents listed in the "Bioremediation Abstracts" section of this Guide, use the number listed in the shaded bar below the abstract. If using the Bioremediation Resource Matrix in the center of the Guide to order documents, use the number listed below the document title. If multiple document ordering numbers are identified, select the appropriate number based on the directions below. EPA/540 and EPA/600 documents may be available through CERI and/or NCEPI. These document repositories provide in-stock documents free of charge, but document supplies may be limited. Prior to purchasing a document through NTIS, you may also wish to review a copy at a technical library.

Document Type	**Document Source**
Publications with the following numbers: EPA/530 EPA/540 EPA/600 EPA/625	Center for Environmental Research Information (CERI) Cincinnati, OH 45268 (513) 569-7562

Out of stock documents may be ordered from NCEPI or may be purchased from NTIS.

Publications with the following numbers: EPA/540 EPA/542 EPA/600	National Center for Environmental Publications and Information (NCEPI) 11029 Kenwood Road, Building 5 Cincinnati, OH 45242 (513) 891-6561 fax requests to (513) 891-6685

A document title or number is needed to place an order with NCEPI. Out of stock documents may be ordered from CERI or may be purchased from NTIS.

Publications with EPA/530 numbers	RCRA Information Center (RIC) 401 M St., S.W. Mailcode: WH-562 Washington, DC 20460 (202) 260-9327

"Order Form for Free Office of Solid Waste Publications," included in the "Order Forms" section of this Guide can be used to order from the RIC.

OSWER Directives (EPA personnel only)	Superfund Document Center 401 M St., S.W. Mailcode: OS-245 Washington, DC 20460 Attn: Superfund Directives (202) 260-9760

Publications with NTIS numbers and Office of Solid Waste and Environmental Response (OSWER) Directives (for Non-EPA personnel)	NTIS 5285 Port Royal Road Springfield, VA 22161 (703) 487-4650

NTIS provides documents for a fee. "NTIS Order Form," included in the "Order Forms" section of this Guide can be used to order from NTIS.

If you have difficulty finding a document, call:

RCRA/Superfund/UST Hotline 1-800-424-9346
Operates Monday-Friday, 8:30 a.m. - 7:30 p.m., Eastern Time.

Hotline staff can help EPA staff or members of the public locate documents and assist callers with placing document orders.

SOURCES OF BIOREMEDIATION INFORMATION/ TECHNICAL ASSISTANCE

Numerous computer-based bulletin boards, regulatory hotlines, dockets, databases, catalogs, and periodicals are also available. These resources provide technical information on bioremediation and other innovative technologies and guide you to additional valuable resources.

BULLETIN BOARDS:

- **Alternative Treatment Technologies Information Center (ATTIC) (data line) 301-670-3808**
  To obtain information on ATTIC 908-906-6828
  A collection of hazardous waste databases accessed through a bulletin board that provides hazardous waste abstracts, news bulletins, conference information, and a message board.

- **Cleanup Information Bulletin (CLU-IN) (data line) 301-589-8366**
  A bulletin board for hazardous waste professionals that provides current information on innovative technologies. Provides information bulletins, message and on-file exchange, and on-line databases and directories.

  Help Line 301-589-8368
  Addresses questions about CLU-IN access and contents; addresses problems with the service.

- **Office of Research and Development (ORD) (data line) 800-258-9605**
  Bulletin Board Service (BBS) (data line) 513-569-7610
  Provides a bibliography of 18,000 documents, news excerpts from "Bioremediation in the Field," and a message board.

  Help Line 513-569-7272
  Provides information on access to and contents of the ORD BBS.

CATALOGS:

- **Catalog of Hazardous and Solid Waste Publications, *Sixth Edition*** *EPA/530-B-92-001*
  Catalogs Office of Solid Waste policy directives, guidance documents, brochures, Regulatory Development Branch memos, and other documents relevant to hazardous and solid waste.

- **Compendium of Superfund Program Publications**
  EPA/540/8-91/014, NTIS PR 881
  Provides abstracts and ordering information for fact sheets, directives, publications, and computer materials on Superfund. Use the document ordering directions to compendium.

DATABASES:

- **DIALOG Database 800-3-DIALOG**
  A large database that contains files relevant to hazardous waste including: Biotechnology Abstracts; Enviroline; Corrective Action Search; Pollution Abstracts; National Technical Information Services (NTIS); and others.

- **NTIS Database**
  Contains abstracts of government-sponsored research, development, and engineering analyses prepared by approximately 250 Federal agencies and some State and local governments. Accessible via the DIALOG system.

- **Records of Decision System (RODS) (To get information on accessing RODs) 703-603-8881**
  Contains the full text of all signed Records of Decision for hazardous waste clean-up sites nationwide. Direct access to RODS is available to EPA personnel and organizations that have relevant EPA contracts.

- **Vendor Information System for Innovative Treatment Technologies (VISITT) 800-245-4505**
  Contains current information on availability, performance, and cost of innovative technologies to remedy hazardous waste sites.

DOCKETS:

- **Federal Facilities Docket Hotline 800-548-1016**
  Provides the name, address, NPL status, agency, and Region for the 1,930 Federal facilities listed on the Federal Facilities Docket. Facilities are on the docket because they reported being a RCRA TSDF or having spilled or having the potential to release CERCLA hazardous waste. Operates Monday - Friday, 8 a.m. - 6 p.m., Eastern Time.

- **RCRA Information Center 202-260-9327**
  Indexes and provides public access to all regulatory materials supporting the Agency's actions under RCRA, and disseminates current Office of Solid Waste publications. Operates Monday - Friday, 8:30 a.m. - 4 p.m., Eastern Time.

- **Superfund Docket 202-260-3046**
  Provides access to Superfund regulatory documents, Superfund Federal Register Notices, and Records of Decision. Operates Monday - Friday, 9 a.m. - 4 p.m., Eastern Time.

- **UST Docket 202-260-9720**
  Provides documents and regulatory information pertinent to RCRA's Subtitle I (the Underground Storage Tank program). *Operates Monday - Friday, 9 a.m. - 4 p.m., Eastern Time.*

HOTLINES/REGULATORY/TECHNICAL ASSISTANCE:

- **EPA Headquarters Library 202-260-5921**
  Offers reports from various EPA offices and trade and environmental journals. Features the "Hazardous Waste Collection" department. Operates Monday - Friday, 10 a.m. - 4 p.m., Eastern Time.

- **RCRA/Superfund/UST Hotline 800-424-9346**
  Provides regulatory assistance related to RCRA, CERCLA, and UST programs. Serves as a liaison between the regulated community and EPA personnel and provides information on the availability of relevant documents. Operates Monday - Friday, 8:30 a.m. - 7:30 p.m., Eastern Time.

- **TSCA Hotline 202-554-1404**
  Answers public and private regulatory questions on TSCA. Refers callers to appropriate EPA contacts, and takes TSCA-relevant document orders. Operates Monday - Friday, 8:30 a.m. - 5 p.m., Eastern Time.

- **Superfund Health Risk Technical Support Center 513-569-7300**
  Provides EPA Regional Superfund risk assessors, State agencies, and those working under EPA contract with technical, typically chemical-specific, support and risk assessment review. Operates Monday - Friday 8 a.m. - 5 p.m., Eastern Time.

INFORMATION CENTER:

- **National Center for Environmental Publications and Information (NCEPI) 513-891-6561**
  (Fax requests) 513-891-6685
  Stores and distributes to public and private callers a limited supply of most EPA publications, videos, posters, and other multi-media materials. Callers should know document titles or numbers when calling. The following periodicals can be obtained from NCEPI, as supplies last:

- **Bioremediation in the Field**
  A periodical devoted to bioremediation that contains 140 potential applications of bioremediation, including site type, name, and contact.

- **Groundwater Currents**
  A newsletter that reports on innovative in-situ and ex-situ groundwater remediation technologies to be applied in the field.

- **Tech Trends**
  An applied technology journal that provides information on Superfund removals, remedial actions, and RCRA corrective actions.

FEDERAL REGULATIONS AND GUIDANCE RELEVANT TO BIOREMEDIATION

This table lists pertinent RCRA regulations, with the *Code of Federal Regulations (CFR)* and *Federal Register (FR)* citations. This table provides information on guidance documents relevant to these regulations. It is important to note that many of these Federal regulations are considered optional. As such, States may choose not to become authorized for these provisions. In addition, States may elect to have more stringent regulations than the Federal regulations identified here. Contact your State environmental protection agency when considering the applicability of any of the following Federal regulations.

CITATION	REGULATION	DESCRIPTION	GUIDANCE
40 *CFR* §261.4(e)-(f) July 19, 1988 53 *FR* 27290	**Treatability Study Exemption**	Allows for treatability studies under RCRA	Conducting Treatability Studies Under RCRA (7/92, OSWER Directive 9380.3-09FS, NTIS PB92-963-501)
40 *CFR* §270.65 July 15, 1985 50 *FR* 28728	**Research Development and Demonstration Permits**	Allows the issuance of a RCRA permit for a pilot scale study pertaining to an innovative or experimental technology	EPA Guidance Manual for Research Demonstration and Design Permits (7/86, EPA/530-SW-86- 008, OSWER Directive 9527.00-1A)
40 *CFR* §264.600 December 10, 1987 52 *FR* 461164	**Subpart X Miscellaneous Units**	Allows the issuance of a RCRA permit for a miscellaneous unit	
40 *CFR* §270.42(e) March 7, 1989 54 *FR* 9596 (Changes certain permit modifications for hazardous waste)	**RCRA Permit Modification Rule: Temporary Authorization**	Allows the permitting agency to grant a facility a temporary authorization to perform certain activities (e.g., cleanups, corrective action and closure activities) for up to 180 days	Modify RCRA Permits (9/89, EPA/530-SW-89-050)
40 *CFR* §268.40 June 1, 1990 55 *FR* 22686 (Presents third third wastes)	**Land Disposal Restrictions (LDR) Subpart D - Treatment Standards**	Sets forth RCRA hazardous waste treatment standards	Land Disposal Restrictions Summary of Requirements (2/91, OSWER Directive 9934.0-1A)
40 *CFR* §268.45 August 18, 1992 57 *FR* 37279	**Treatment Standards for Hazardous Debris**	Discusses biological destruction of hazardous constituents from debris surface	
40 *CFR* §268.44(h) August 17, 1988 53 *FR* 31143, 31185, 31188, 31196, 31199, 31202 (presents final rule on first third wastes and national capacity variances)	**Variance from an LDR Treatment Standard**	Allows for a site-specific treatability variance to be issued as a nonrulemaking procedure	Regional Guide: Issuing Site-Specific Treatability Variances for Contaminated Soils and Debris from LDRs (1/92, OSWER Directive 9380.3-08FS)
40 *CFR* §260, 264.552 et al February 16, 1993 58 *FR* 8658 (Presents final CAMU rule) July 27, 1990 55 *FR* 30842-30845 (Proposes corrective action & CAMU)	**Corrective Action Management Unit (CAMU)**	Encourages treatment, including use of innovative treatment (specifically bioremediation), instead of containment	Environmental Fact Sheet: EPA Issues Final Rules for Corrective Action Management Units and Temporary Units (1/93, EPA/530-F-93-001)

ABSTRACTS OF BIOREMEDIATION RESOURCES

The following abstracts describe the contents of pertinent bioremediation documents and are categorized by document type. Document types included in this Section are:

Begins on Page

- Bibliographies 6
- Guidance/Workshops 8
- Overview Documents 10
- Study/Test Results 13
- Test Designs/Protocols 24
- Examples of Other Relevant Documents 26

To quickly identify documents pertinent to your interest area, see the **Bioremediation Resource Matrix** in the center of this Guide. The documents in the matrix are categorized using the document types identified above and can be cross-referenced with the abstracts using the code to the left of the document titles on the matrix. In an effort to limit the number of resources listed here, documents on oil spills, waste minimization, natural process bioremediation, leaching/immobilization, ex-situ bioremediation, and other media (e.g., air and surface water) as well as Records of Decision and proceedings are not included. Samples of documents focused on ex-situ bioremediation of wastewater and leachate using a biofilter and a bioreactor are included. However, those seeking information on these topics or other topics not addressed in this Guide may wish to contact the hotlines, dockets, etc. listed on page 4 of this Guide. These abstracts were pulled from a TIO literature survey under development and the NTIS Database.

BIBLIOGRAPHIES

6A

Biodegradation of Pesticides. (Latest citations from the NTIS Database), (Published Search).
NERAC, Inc., Tolland, CT, November 1992

NTIS Document Number: PB93-854297/XAB

The bibliography contains citations concerning the biodeterioration of pesticides in soil and water by naturally occurring microbes, chemicals, and microbial innoculants. The citations examine the kinetics and metabolic process of pesticide biodegradation, and include means to enhance the process. Mathematical models are also included. (Contains a minimum of 61 citations and includes a subject term index and title list.)

6B

Biodegradation of Toxic Wastes. (Latest citations from the Energy Database), (Published Search).
NERAC, Inc., Tolland, CT, October 1992

NTIS Document Number: PB93-851699/LL

The bibliography contains citations concerning the use of bacteria to decompose hydrocarbons and other hazardous materials. Microbial breakdown of coal wastewater, jet fuel, phenols, and cyanides is also discussed. Cost comparisons between biodegradation and conventional physical and chemical methods are considered briefly. (Contains 250 citations and includes a subject term index and title list.)

6C

Bioremediation, January 1988-March 1992 (Citations from the NTIS Database).
National Technical Information Service, Springfield, VA, February 1992

NTIS Document Number: PB93-868602/LL

The bibliography contains citations concerning the decomposition of toxic materials by biological means. Bacterial decomposition of jet fuel, wood preservatives, explosives, crude oil, halogenated organics, diesel fuel, aviation fuel, and creosote are discussed. Enhancement of decomposition rates by addition of nutrients is also included.

6D

Federal Publications on Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: Second Edition.
Member Agencies of the Federal Remediation Technologies Roundtable: U.S. Environmental Protection Agency, U.S. Department of Defense, U.S. Air Force, U.S. Army, U.S. Navy, U.S. Department of Energy, U.S. Department of Interior, Washington, DC, August 1992

EPA Document Number: 542/B-92/001

NTIS Document Number: PB93-145696/LL

The Federal Remediation Technologies Roundtable developed this bibliography to publicize the availability of Federal documents pertaining to innovative and alternative technologies to treat hazardous waste. The bibliography addresses technologies that provide for the treatment of hazardous waste. It emphasizes innovative technologies for which detailed cost and performance data are not available. It includes citations for documents addressing: international surveys and conferences; technology survey reports; treatability studies; groundwater; thermal processes; biological; physical/chemical; and community relations. Citations provided here will supplement listings in this Guide.

7A

Hazardous Materials: Microbiological Decomposition. (Latest citations from the BioBusiness Database).
National Technical Information Service, Springfield, VA, May 1992

NTIS Document Number: PB92-853985/XAB

The bibliography contains citations concerning the decomposition of toxic materials by biological means. Bacteria, enzymes, and bioluminescence are among the methods discussed. Bacteria and enzymes that digest toluene, polychlorinated biphenyls (PCBs), selenium wastes, oil shale waste, uranium, oil sludge, pesticides, rubber wastes, and pentachlorophenol are discussed. Flavobacterium and white rot fungus are among the biological agents highlighted. (Contains 250 citations and includes a subject term index and title list.)

7B

Literature Survey of Innovative Technologies for Hazardous Waste Site Remediation, 1987-1991.
U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC, July 1992

EPA Document Number: 542/B-92/004

NTIS Document Number: PB93-105617/XAB

EPA's Office of Solid Waste and Emergency Response is seeking to further the use of innovative hazardous waste treatment technologies in its programs. In order to achieve more permanent remedies, the Agency is encouraging the use of new or innovative technologies that are capable of treating contaminated soils/sludges and groundwater more effectively, less expensively, and in a manner more acceptable to the public than existing conventional methods. The bibliography is intended to increase the efficiency of the technology evaluation process. The document is not meant to be comprehensive in scope nor is it meant to convey an endorsement of the citations. It is meant to provide a survey of publications which could be useful when innovative technologies are investigated. As a research aid, the bibliography can help provide insights into current developments and provide references which may serve as a basis for further investigations.

7C

Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation, (A Bibliography of EPA Information Resources), Winter Update.
U.S. Environmental Protection Agency, Washington, DC, January 1993

EPA Document Number: 542/B-93/001

This bibliography provides citations for documents relevant to alternative and innovative treatment technologies applicable at Superfund and RCRA sites. The bibliography also includes: conferences and international surveys; technology survey reports/guidance; treatability studies documents; groundwater documents; technology support documents; physical/chemical treatment documents; community relations documents; bulletin boards and databases; and technology newsletters. Citations provided here will supplement listings in this Guide.

7D

Subsurface Science Program Bibliography, 1985-1992, (Bibliography).
U.S. Department of Energy, Office of Health and Environmental Research, Washington, DC, August 1992

NTIS Document Number: DE92-040642/XAB

The Subsurface Science Program sponsors long-term basic research on (1) the fundamental physical, chemical, and biological mechanisms that control the reactivity, mobilization, stability, and transport of chemical mixtures in subsoils and groundwater; (2) hydrogeology, including the hydraulic, microbiological, and geochemical properties of the vadose and saturated zones that control contaminant mobility and stability, including predictive modeling of coupled hydraulic-geochemical-microbial processes; and (3) the microbiology of deep sediments and groundwater. This research, focused as it is on the natural subsurface environments that are most significantly affected by the more than 40 years of waste generation and disposal at DOE sites, is making important contributions to cleanup of DOE sites. Past DOE waste-disposal practices have resulted in subsurface contamination at DOE sites by unique combinations of radioactive materials and organic and inorganic chemicals (including heavy metals), which make site cleanup particularly difficult. The long- term (10- to 30-

year) goal of the Subsurface Science Program is to provide a foundation of fundamental knowledge that can be used to reduce environmental risks and to provide a sound scientific basis for cost-effective cleanup strategies. The Subsurface Science Program is organized into nine interdisciplinary subprograms, or areas of basic research emphasis. The subprograms currently cover the areas of Co-Contaminant Chemistry, Colloids/Biocolloids, Multiphase Fluid Flow, Biodegradation/ Microbial Physiology, Deep Microbiology, Coupled Processes, Field-Scale (Natural Heterogeneity and Scale), and Environmental Science Research Center.

GUIDANCE/WORKSHOPS

8A

Bioremediation of Hazardous Waste Sites Workshop; Speaker Slide Copies and Supporting Information.
U.S. Environmental Protection Agency, Center for Environmental Research Information, Cincinnati, OH, February 1989

NTIS Document Number: PB89-169205/XAB

Basic requirements for implementing biological systems to remediate hazardous wastes initial data requirements; example site for bioremediation; reactor design; and in-situ design.

8B

Biotechnology Workgroup for Department of Defense Soil and Groundwater Decontamination Applications; Final Report for Period Ending March 1989.
Reuter, R. H., Life Systems Inc., Cleveland, OH, Naval Civil Engineering Lab, Port Hueneme, CA, June 1991

NTIS Document Number: ADA237 956/8/XAB

This report contains materials used in and generated by the Department of Defense Biotechnology Workshop on Soil and Groundwater Decontamination Applications. Various bioremediation techniques for treating soil and water contaminated with sludges, solvents, toxins, acids, bases, and heavy metals were discussed as well as the overall place of biotechnology in Installation Restoration programs. Among the specific applications discussed were: biochemical sensors to determine environmental stress in organisms; in-situ detoxification and biodecontamination of pollutants in soils and waste streams; sequestration, removal, and recovery of metals in waste streams with metal-binding proteins; and the use of vegetation to limit the transport to sequester, and/or to remove contaminants from soil or water.

8C

Contaminants and Remedial Options at Wood Preserving Sites.
Selvakumar, A.; Sudell, G.; and Wolf, G., Foster Wheeler Enviresponse, Inc., Edison, NJ, October 1992

NTIS Document Number: PB92-232222/XAB

The report will assist Federal, State, or private, site removal and remedial managers operating under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), or State rules. It provides information that facilitates the selection of treatment technologies and services at wood preserving sites, in order to meet the regulations' acceptable levels of cleanliness. Within the context of the United States wood preserving industry, the reference identifies the sources and types of wood preserving contaminants, characterizes them, and defines their behavior in the environment. It addresses the goals in technology selection and describes the principal remedial options for contaminated wood preserving sites. It also considers ways to combine these options to increase treatment efficiency. Finally, this remedial aid provides a comprehensive bibliography, organized by its relevance to each section, to complement the information offered in these pages.

8D

Environmental Biotechnology of Hazardous Wastes Research Planning Workshop, The National Science Foundation.
Blackburn, J.W.; Donaldson, T.L.; and Sayler, G.S., and Oak Ridge National Laboratory., Oak Ridge, TN, Tennessee University, Knoxville, TN, Center for Environmental Biotechnology, U.S. Department of Energy, Washington, DC, August 1988

NTIS Document Number: DE89-001340/XAB

Environmental biotechnology is "the direct use of microorganisms and their capabilities to solve environmental problems and for in-situ agricultural applications and industrial waste treatment." Environmental biotechnology is at the interface between responsible disciplines in engineering, molecular biology, and ecological sciences. The purpose of this research planning effort was to define limitations in the current knowledge base and to develop a research agenda and strategy that will lead to the successful practice of environmental biotechnology. The focus was specifically directed at environmental protection. However, it was recognized that the research plan

typifies a central research model for the future development of effective and ecologically sound biotechnology for other environmental applications.

9A

Guidance Manual on Hazardous Waste Land Treatment Closure/Post-Closure, 40 CFR Part 265 Final Report.
Sims, J.L. and Sims, R.C., Utah State Univ., Logan, UT, Department of Civil and Environmental Engineering, Sponsored by the U.S. Environmental Protection Agency, Office of Solid Waste, Washington, DC, April 1987

EPA Document Number: 68-01-7266

NTIS Document Number: PB87-183695/XAB

The guidance manual addresses closure/post-closure of hazardous waste land treatment (HWLT) units under 40 CFR Part 265 Subpart G and Section 265.280 of Subpart M. The manual specifically addresses five areas: (1) general information on HWLT and methods of closure; (2) objectives of closure and post-closure; (3) factors affecting closure and post-closure; (4) methods for addressing closure and post-closure based on migration potential; and (5) management during closure and post-closure.

9B

Innovative Technology: Slurry-Phase Biodegradation Fact Sheet (Final).
U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, November 1989

NTIS Document Number: PB90-274200/XAB

The fact sheet provides technology description, site characteristics affecting treatment feasibility, technology considerations, and technology status for Slurry Phase Biodegradation (SPB). The sheet describes how SPB is potentially effective in treating various organic contaminants.

9C

Methodologies for Evaluating In-Situ Bioremediation of Chlorinated Solvents, Research Report August 21, 1989 - June 14, 1991.
Grbic-Galic, D.; McCarty, P.L.; Roberts, P.V.; and Semprini, L., Stanford University, CA, Department of Civil Engineering, Robert S. Kerr Environmental Research Laboratory, Ada, OK, March 1992

EPA Document Number: 600/R-92/042

NTIS Document Number: PB92-146943/XAB

The report summarizes the behavior of and requisite conditions for a class of natural biological processes that can transform chlorinated aliphatic compounds. These compounds are among the most prevalent hazardous chemical contaminants found in municipal and industrial wastewaters, landfills and landfill leachates, industrial disposal sites, and groundwater. Biological degradation is one approach that has the potential for destroying hazardous chemicals so that they can be rendered harmless for all time. Methodologies are presented that are useful for evaluating the potential for biorestoration of groundwater contaminated with chlorinated aliphatic compounds. Section 1 provides an introduction and an overview of the problems with chlorinated aliphatic compounds in groundwater. Section 2 presents a review of the processes affecting the movement and fate of chlorinated aliphatics in the subsurface, including advection, dispersion, sorption and relative mobility, diffusional transport, and immiscible transport. Methodologies and results are presented for evaluating the presence of a native methantrophic community and its ability to degrade the contaminants of concern; determining the sorption of contaminants to the aquifer material; and preliminary designing of an in-situ treatment approach using the model previously described.

9D

"No Migration" Variances to the Hazardous Waste Land Disposal Prohibitions: A Guidance Manual for Petitioners.
U.S. Environmental Protection Agency, Office of Solid Waste, Washington, DC, March 1990

EPA Document Number: 530/SW-90/045

NTIS Document Number: PB90-204736/XAB

This manual is intended to assist hazardous waste management facility owners and operators who may be considering petitioning the U.S. Environmental Protection Agency for variance from land disposal prohibitions at specific sites for specific wastes. The guidance manual also provides the EPA interpretation and suggested procedures to implement the regulatory standards and procedures set out in 40 CFR 268.6. This manual also contains descriptions of additional requirements for "no migration" petitions in the Land Disposal Restrictions First Third Rule.

9E

Rotating Biological Contactors. Engineering Bulletin.
U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, October 1992

EPA Document Number: 540/S-92/007

NTIS Document Number: PB92-235936/XAB

Rotating biological contactors employ aerobic fixed-film treatment to degrade either organic and/or nitrogenous (ammonia-nitrogen) constituents present in aqueous waste streams. Fixed-film systems provide a surface to which the biomass can adhere. Treatment is achieved as the waste passes by the media, enabling fixed-film systems to acclimate biomass capable of degrading organic waste. Fixed-film rotating biological contactor reactors provide a surface to which soil organisms can adhere; many indigenous soil organisms are effective degraders of hazardous wastes. The bulletin provides information on the technology applicability, the technology limitations, a description of the technology, the types of residuals produced, site requirements, the latest performance data, the status of the technology, and sources of further information.

10A

Slurry Biodegradation Engineering Bulletin.
Science Applications International Corporation, Cincinnati, OH, Sponsored by the U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, September 1990

EPA Document Number: 68-C8-0062

NTIS Document Number: PB91-228049/XAB

In a slurry biodegradation system, an aqueous slurry is created by combining soil or sludge with water. This slurry is then biodegraded aerobically using a self-contained reactor or in a lined lagoon. Thus, slurry biodegradation can be compared to an activated sludge process or an aerated lagoon, depending on the case. There are two main objectives for using the technology: to destroy the organic contaminant and, equally important, to reduce the volume of contaminated material. Slurry biodegradation can be the sole treatment technology in a complete cleanup system, or it can be used in conjunction with other biological, chemical, and physical treatment. It may be demonstrated in the Superfund Innovative Technology Evaluation (SITE) program. Commercial-scale units are in operation. Vendors should be contacted to determine the availability of a unit for a particular site. The bulletin provides information on the technology applicability, the types of residuals produced, the latest performance data, site requirements, the status of the technology, and sources for further information.

OVERVIEW DOCUMENTS

10B

Bioprocessing Applications in the Management of Nuclear and Chemical Wastes.
Genung, R.K., Oak Ridge National Laboratory, TN, U.S. Department of Energy, Washington, DC, November 1988

NTIS Document Number: DE89-003368/XAB

The projected requirements for waste management and environmental restoration activities within the United States will probably cost tens of billions of dollars annually during the next two decades. Expenditures of this magnitude clearly have the potential to affect the international competitiveness of many US industries and the continued operation of many Federal facilities. It is argued that the costs of implementing current technology will be too high unless the standards and schedules for compliance are relaxed. Since this is socially unacceptable, efforts to improve the efficiency of existing technologies and to develop new technologies should be pursued. A sizable research, development, and demonstration effort can be easily justified if the potential for reducing costs can be shown. Bioprocessing systems for the treatment of nuclear and chemically hazardous wastes offer such promise.

10C

Bioremediation: An Information Update on Applying Bioremediation to Site Cleanup.
U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC, March 1992

EPA Document Number: 540/N-92/001

NTIS Document Number: PB93-126175/XAB

The Bioremediation Field Initiative was established to provide the U.S. Environmental Protection Agency (EPA) and State Project Managers, consulting engineers, and industry with timely information regarding new developments in the application of bioremediation at hazardous waste sites. The initiative provides evaluation of the performance of selected full-scale field applications; provides technical assistance to Remedial Project Managers (RPMs) and On-Scene Coordinators (OSCs), through the Technical Support Centers; and is developing a database on the field applications of bioremediation, which is summarized in this bulletin.

10D

Critical Review of In-Situ Bioremediation Topical Report, January 1990 - March 1992.
Ray, C.; Rittmann, B.E.; Seagren, E.; Valocchi, A.J.; and Wrenn, B., Illinois University at Urbana-Champaign, IL, Newmark Civil Engineering Laboratory, March 1992

NTIS Document Number: PB93-114247/XAB

In-situ bioremediation, which is the managed, in-place cleanup of contaminated groundwater aquifers and surface soils by microorganisms, is a promising technology because it

is versatile and can have significant economic advantages. Many common contaminants are biodegradable, and new microbial capabilities for degradation are being discovered all the time. Success in the field and in laboratory studies point out the promise. On the other hand, the promises are not yet fulfilled, mainly because of the complexity of the subsurface situation. The report provides a comprehensive and in-depth critical review of in-situ bioremediation. It is organized to evaluate the possibilities and restrictions inherent in all facets of in-situ bioremediation, including microbiology, hydrodynamics, engineering, and its legal and other nontechnical aspects. Several of the key conclusions are illustrated by case studies of successful field projects. Finally, the research needed to advance in-situ bioremediation to become a reliable and acceptable tool is outlined.

11A

Hazardous Waste Land Treatment: A Technology and Regulatory Assessment.
Brown, K.W.; Evans, G.B.; and Overcash, M., Argonne National Laboratory, IL, U.S. Department of Energy, Washington, DC, September 1987

NTIS Document Number: DE88-005571/XAB

Land treatment is a waste management technology that provides a high level of treatment for some hazardous wastes by using the soil as a treatment medium to degrade, transform, or immobilize waste constituents. It is characterized by very long retention times, and its costs are comparable to or lower than those of other waste treatment or disposal technologies. Also, most land treatment sites can be returned to unrestricted use after closure. Research and field experience for hazardous waste land treatment (HWLT) has demonstrated that a wide range of elements and compounds are treatable in a soil-based system. Also, studies show that heavy metals and organics are unlikely to migrate under HWLT conditions; preliminary studies of emission levels of volatile compounds show that they comply with regulatory requirements. However, because HWLT is regulated as "land disposal" (a term that incorrectly describes it), its widespread adoption is constrained. If hazardous waste regulations are changed to regulate HWLT as a separate treatment technology, it could be further developed and integrated into the US hazardous waste management system.

11B

In-Situ/On-Site Biodegradation of Refined Oils and Fuels. (A Technology Review).
Riser-Roberts, E., Naval Civil Engineering Laboratory, Port Hueneme, CA, June 1992

NTIS Document Number: ADA252681/2/XAB

This extensive literature review covers all aspects of in situ and on-site bioremediation of gasoline, middle distillate fuels, and other refined petroleum products, using information available through 1988. Topics covered include: composition of different fuels, factors affecting biodegradation rates, responsible microorganisms, degradation pathways, factors enhancing biodegradation, and potential limitations. This report is in three volumes. Volume 1 covers general information of most interest to managers and non-specialists. Volume 2 contains technical information required for in-depth coverage. Volume 3 covers related information, including detailed applied information on screening and microbial enumberation methods, laboratory microorganism studies, bioreclamation site preparation, bioreactor use and selection, cost data, and competing technologies.

11C

Literature Review and Preliminary Assessment of Biological Transformations and Biotreatment Technology for Petroleum Hydrocarbons and Chlorinated Solvents.
Korte, N.E., Oak Ridge National Laboratory, TN, Washington, DC, Sponsored by the U.S. Department of Energy, Washington, DC, December 1990

NTIS Document Number: DE91-007871/XAB

Chlorinated solvents and petroleum hydrocarbons may undergo a number of natural degradation processes when applied to soil or groundwater. Indeed, the existence of these reactions has led to extensive research and the development of biodegradation as a remedial action technique. Unfortunately, the scientific literature demonstrates that there is considerable controversy concerning many aspects of the field. For example, different investigators are often unable to agree on relative rates of biodegradation or even whether certain compounds are biodegradable. This report examines the recent scientific literature, describes the biodegradation reactions that are known to occur, and discusses some of the controversies. The potential value of biodegradation for remedial action of soils and groundwater is also presented both from a review of the literature and from interviews with remedial action contractors.

11D

Low-Temperature Effects on Systems for Composting of Explosives-Contaminated Soils, Part 1. Literature Review Special Report.
Ayorinde, O.A. and Reynolds, C.M., Cold Regions Research and Engineering Laboratory, Hanover, NH, December 1989

NTIS Document Number: ADA219352/2/XAB

This report reviews literature on the influence of major parameters on composting, with emphasis on temperature and explosives. Heat energy is produced by composting as a result of a microbial conversion of chemical energy to thermal energy. Hence, heat production and transfer, the influence of engineering design on compost pile temperatures, and the control and measurement of compost pile temperature are also examined. In addition, the report includes a general discussion on composting, fundamental composting principles, available types of composting systems, applications of composting technology, and the established parameters that influence composting under various environmental conditions that may be applicable to cold regions' treatment of hazardous waste.

12A

Overview of In-Situ Waste Treatment Technologies.
Hyde, R.A.; Piper, R.B.; Roy; M.W.,Walker, S., EG and G Idaho, Inc., Idaho Falls, ID, 1992

NTIS Document Number: DE92-018012/XAB

In-situ technologies are becoming an attractive remedial alternative for eliminating environmental problems. In-situ treatments typically reduce risks and costs associated with retrieving, packaging, and storing or disposing-waste and are generally preferred over ex-situ treatments. Each in-situ technology has specific applications, and, in order to provide the most economical and practical solution to a waste problem, these applications must be understood. This paper presents an overview of thirty different in-situ remedial technologies for buried wastes or contaminated soil areas. The objective of this paper is to familiarize those involved in waste remediation activities with available and emerging in-situ technologies so that they may consider these options in the remediation of hazardous and/or radioactive waste sites. Several types of in-situ technologies are discussed, including biological treatments, containment technologies, physical/chemical treatments, solidification/stabilization technologies, and thermal treatments. Each category of in-situ technology is briefly examined in this paper. Specific treatments belonging to these categories are also reviewed. Much of the information on in-situ treatment technologies in this paper was obtained directly from vendors and universities and this information has not been verified.

12B

Reductive Dehalogenation: A Subsurface Bioremediation Process, Journal Article.
Sims, J.L.; Suflita, J.M.; and Russell, H.H., Robert S. Kerr Environmental Research Laboratory, Ada, OK, Utah Water Research Lab, Logan, UT, Oklahoma University, Norman Department of Botany and Microbiology, 1990

NTIS Document Number: PB91-144873/XAB

Introduction and large-scale production of synthetic halogenated organic chemicals over the last 50 years has resulted in a group of contaminants that tend to persist in the environment and resist both biotic and abiotic degradation. The low solubility of these types of contaminants, along with their toxicity and tendency to accumulate in food chains, make them particularly relevant targets for remediation activities. Among the mechanisms that result in dehalogenation of some classes of organic contaminants are stimulation of metabolic sequences through introduction of electron donor and acceptor combinations; addition of nutrients to meet the needs of dehalogenating microorganisms; possible use of engineered microorganisms; and use of enzyme systems capable of catalyzing reductive dehalogenation. The current state of research and development in the area of reductive dehalogenation is discussed along with possible technological application of relevant processes and mechanisms to remediation of soil and groundwater contaminated with chlorinated organics. In addition, an overview of research needs is suggested, which might be of interest for development of in-situ systems to reduce the mass of halogenated organic contaminants in soil and groundwater.

12C

Reductive Dehalogenation of Organic Contaminants in Soils and GroundWater. GroundWater Issue.
Sims, J.L.; Suflita, J.M.; and Russell, H.H., Robert S. Kerr Environmental Research Lab, Ada, OK, January 1991

NTIS Document Number: PB91-191056/XAB

Introduction and large scale production of synthetic halogenated organic chemicals over the last 50 years has resulted in a group of contaminants which tend to persist in the environment and resist both biotic and abiotic degradation. The low solubility of these types of contaminants, along with their toxicity and tendency to accumulate in food chains, make them particularly relevant targets for remediation activities. Although the processes involved in dechlorination of many of these organic compounds are well understood in the fields of chemistry and microbiology, technological applications of these processes to environmental remediation are relatively new—particularly at pilot or field scale. It is well established, however, that there are several mechanisms which result in dehalogenation of some classes of organic contaminants, often rendering them less offensive environmentally. These include: stimulation of metabolic sequences through introduction of electron donor and acceptor combinations; addition of nutrients to meet the needs of dehalogenating microorganisms; possible use of engineered micro-organisms; and use of enzyme systems capable of catalyzing reductive dehalogenation.

13A

Report on Decontamination of PCB-Bearing Sediments, Final Report.
Wilson, D.L., U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, October 1987

NTIS Document Number: PB88-113220/XAB

The EPA has initiated a research program to identify chemical/biological methods as alternatives to incineration and to chemical land disposal for cleanup of polychlorinated biphenyls (PCB)-contaminated sediments. The overall objective of the program is to identify, validate, and demonstrate effective and economical chemical/biological processes for removal/destruction of PCBs in sediments. The report summarizes research progress on chemical/biological methods development for the detoxification/destruction of PCBs in sediments.

13B

Status of Land Treatment as a Hazardous Waste Management Alternative in the United States.
Matthews, J.; McFarland, M.; and Sims, R., et al., U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Cincinnati, OH, 1989

NTIS Document Number: PB91-196105/XAB

Land treatment systems are widely used in the United States for treating petroleum refinery waste. Many of the petroleum compounds are degradable in bench scale studies. Proper operation of the treatment is critical for successful performance.

13C

Use of Innoculation in Bioremediation, Journal Article.
Pritchard, P.H., Environmental Research Laboratory, Gulf Breeze, FL, 1992

EPA Document Number: 600/J-92/383

NTIS Document Number: PB93-121150/XAB

The potential for inoculating chemically-polluted sites with microorganisms to foster the removal or degradation of contaminating organic materials (and some inorganic materials) has been recognized. The purpose of this review is to address and discuss several important aspects that may help define problems associated with inoculation in bioremediation and to thereby provide an indication of the research needed to allow this process to become a meaningful and productive element of bioremediation technologies.

STUDY/TEST RESULTS

13D

Alternative Biological Treatment Processes for Remediation of Creosote- and PCP-Contaminated Materials: Bench-Scale Treatability Studies.
Blattman, B.O.; Lantz, S.E.; and Mueller, J.G., et al., Southern BioProducts, Inc., Pendleton, SC, Prepared in cooperation with Technical Resources, Inc., Gulf Breeze, FL, Sponsored by the Environmental Research Laboratory, Gulf Breeze, FL, March 1991.

EPA Document Number: 68-033479

NTIS Document Number: PB91-179085/XAB

Bench-scale biotreatability studies were performed to determine the most effective of two bioremediation application strategies to ameliorate creosote- and pentachlorophenol (PCP)-contaminated soils present at the American Creosote Works Superfund site, Pensacola, Florida: solid-phase bioremediation or slurry-phase bioremediation. When indigenous microorganisms were employed as biocatalysts, solid-phase bioremediation was slow and ineffective (8-12 weeks required to biodegrade >50% of resident organics). Biodegradation was limited to lower-molecular-weight constituents rather than the more hazardous, higher-molecular-weight (HMW) compounds; PCP and HMW polycyclic aromatic hydrocarbons (PAHs) containing four or more fused rings resisted biological attach. Moreover, supplementation with aqueous solution of inorganic nutrients had little effect on the overall effectiveness of the treatment strategy. Alternatively, slurry-phase bioremediation was much more effective: >50% of targeted organics were biodegraded in 14 days. Again, however, more persistent contaminants, such as PCP and HMW PAHs, were not extensively degraded when subjected to the action of indigenous microorganisms.

13E

Approach to Bioremediation of Contaminated Soil, Journal Article: Published in *Hazardous Waste and Hazardous Materials*, v26n2, 1990.
Matthews, J. E.; Sims, J.L.; Sims, R.C.; and Utah State University, Logan, UT, Robert S. Kerr Environmental Research Laboratory, Ada, OK

NTIS Document Number: PB91-116152/XAB

Biological processes, including microbial degradation, have been identified as critical mechanisms for attenuating organic contaminants during transit through the vadose zone to the groundwater. On-site soil remedial measures using biological processes can reduce or eliminate groundwater contamination,

thus reducing the need for extensive groundwater monitoring and treatment requirements. On-site remedial systems that utilize the soil as the treatment system accomplish treatment by using naturally occurring microorganisms to treat the contaminants. Treatment often may be enhanced by a variety of physical/chemical methods, such as fertilization, tilling, soil pH adjustment, moisture control, etc. The development of a bioremediation program for a specific contaminated soil system includes: (1) a thorough site/soil/waste characterization; (2) treatability studies; and (3) design and implementation of the bioremediation plan.

14A

Assessing Detoxification and Degradation of Wood Preserving and Petroleum Wastes in Contaminated Soil, Journal Article: Published in *Waste Management and Research*, v8n1, February 1990.
Aprill, W.; Sims, J.L.; and Sims, R.C., et al., Robert S. Kerr Environmental Research Laboratory, Ada, J.L.; OK, Prepared in cooperation with Utah State University, Logan, UT, Department of Civil and Environmental Engineering, 1990

NTIS Document Number: PB90-245275/XAB

The study was undertaken to evaluate in-situ soil bioremediation processes, including degradation and detoxification, for wood preserving and petroleum refining wastes at high concentrations in an unacclimated soil. The soil solid phase, water soluble fractions of soil, and column leachates were evaluated. A mutagenic potential assay (Ames assay) and an aqueous toxicity assay (Microtox(TM) assay) were used to evaluate detoxification; high performance liquid chromatography was used to evaluate chemical concentration and degradation for eight polynuclear aromatic hydrocarbons (PAHs). The group of noncarcinogenic PAHs studied demonstrated greater degradation, ranging from 54-90% of mass added for the wastes; the carcinogenic group of PAHs studied exhibited degradation ranging from 24-53% of mass added. Although no mutagenicity was observed in waste/soil mixtures after one year, Microtox(TM) toxicity was observed in water soluble fractions and in leachate samples. Integration of information concerning degradation of hazardous constituents with bioassay information represents an approach for designing treatability studies and for evaluating effectiveness of in-situ soil bioremediation. When combined with information from waste, site, and soil characterization studies, data generated in treatability studies may be used in predictive models to: evaluate effectiveness of on-site soil bioremediation; develop appropriate containment structures to prevent unacceptable waste transport from the treatment zone; and design performance monitoring strategies.

14B

Assessment of Problems Associated with Landfilling or Land Application of Pesticide Waste and Feasibility of Cleanup by Microbiological Degradation.
Case, L.; Dzantor, E.K.; and Felsot, A., et al., Illinois Department of Energy and Natural Resources, Champaign, IL, Hazardous Waste Research and Information Center, Illinois Natural History Survey, Champaign, IL; Department of Agronomy, Illinois University at Urbana-Champaign, IL. Prepared in cooperation with Illinois Natural History Survey, Champaign, IL, U.S. Department of Agronomy, Illinois University at Urbana-Champaign, IL, October 1990

NTIS Document Number: PB91-121244/XAB

To improve the prospects for use of land application as a remediation tool and the possibility of augmenting biodegradation of pesticide wastes in soil, a series of laboratory experiments were designed to explore microbiological aspects of the persistence of high concentrations of herbicides in soil. Most of the studies focused on the alachlor, which is an acetanilide herbicide used in corn and soybeans. In laboratory experiments, alachlor was not degraded after simulated spills of 1000 ppm or 10,000 ppm. In contrast, 10 ppm and 100 ppm doses of alachlor were partially degraded into water-soluble metabolites. Technical-grade alachlor and an emulsifiable concentrate formulation were metabolized similarly. Microbial populations and dehydrogenase activity in soil were reduced upon exposure to 1000 ppm or 10,000 ppm alachlor, and lack of degradation of these high concentrations was attributed to microbial toxicity from alachlor itself rather than additives in its formulation.

14C

Biodegradation of Hydrocarbons as a Remediation Method for Petroleum Contaminants in the Environment or as a Treatment Method for Petroleum Wastes. (A Review and Analysis of Recent Field Study Literature) (Master's Thesis).
Lubbers, J.E., Kansas University, Lawrence, KS, U.S. Department of Chemical and Petroleum Engineering, December 1989

NTIS Document Number: ADA220718/1/XAB

The U.S. Navy Petroleum Office (NAVPETOFF) is developing future Navy petroleum sludge disposal and soil decontamination procedures. This project was conducted for NAVPETOFF to aid that development by evaluating the use of bacteria to eliminate petroleum hydrocarbons as a disposal or decontamination option. Electronic database searchers, interviews with bioremediation researchers, and manual literature searches were conducted to collect information about microbial bioremediation from sources which postdate the 1984 amendments to RCRA. From that body of information, reports of field applications of microbial bioremediation on petroleum wastes or contaminants were set apart as the primary references for evaluation development. Summaries of reported microbial bioremediation methods were developed are presented. These

summaries are introduced by a review of the biologic limits and processes of the microbes commonly used for bioremediation. The body of these summaries describes and illustrates their techniques. Each summary concludes with an evaluation in the form of a report of the method's effectiveness.

15A

Biodegradation of JP-5 Aviation Fuel by Subsurface Microbial Communities, Progress Report January 1, 1987 - March 15, 1987.

Swindoll, C. M., Naval Engineering Laboratory, Port Hueneme, CA, 1988

NTIS Document Number: ADA192743/3/XAB

Leakage of the aviation fuels JP-5, JP-4 and AVGAS from storage tanks has resulted in a severe environmental insult to a Naval fuel farm and adjacent area. As part of the reclamation effort, the indigenous microorganisms are being characterized. This information will be used to optimize the bioreclamation of the site. Approximately 60 aerobic microorganisms, including more than 40 bacteria, 6 actinomycetes, and 10 fungi have been isolated from soil contaminated with aviation fuels and adjacent non-contaminated with aviation fuels and adjacent non-contaminated soil. All isolated bacteria were able to grow on JP-5 as their sole carbon source. Most of the bacteria from the contaminated sites were small, gram-negative rods, while most bacteria from the non-contaminated site were gram-positive rods. All of these microorganisms would be expected to contribute to the bioremediation of the contaminated site.

15B

Biological Treatment of Soils Containing Manufactured Gas Plant Residues, Topical Report, June 1988 - February 1990.

Cushey, M. A. and Morgan, D.J., Remediation Technologies, Inc., Pittsburgh, PA, Sponsored by Gas Research Institute, Chicago, IL, May 1990

NTIS Document Number: PB90-259961/XAB

The report summarizes the results of an on-going laboratory research program directed by GRI to investigate the feasibility of using biological treatment to remediate soils containing residues from manufactured gas plant (MGP) sites, and to develop and verify a rapid assessment protocol (the GRI Accelerated Treatability Protocol) for determining the potential for biologically treating specific MGP site soils. This protocol, which features soil characterization, desorption testing, and slurry reactor testing, is cost competitive with traditional treatability studies and can be completed in approximately half the time. For the first two soils evaluated, total polynuclear aromatic hydrocarbon (PAH) concentrations (a critical class of chemicals at MGP sites) were reduced by 95 and 80% to residual 'plateau' concentrations of less than 10 and 5,000 mg/Kg, respectively. It is believed that the magnitude of the 'plateau' concentration is not primarily dictated by the availability of nutrients, oxygen, and adequate microbial populations but rather by limitations of mass transfer from the soil-waste matrix to the bulk aqueous phase. Further tests with 13 other MGP soils are in-progress and the results of these will be reported at a later time.

15C

Bioremediated Soil Venting of Light Hydrocarbons, Journal Article: Published in *Hazardous Waste and Hazardous Materials*, v7n4, 1990.

Kampbell, D.H. and Ostendorf, D.W., University of Massachusetts, Amherst, MA, Sponsored by Robert S. Kerr Environmental Research Laboratory, Ada, OK, 1990

NTIS Document Number: PB91-171538/XAB

The effectiveness and feasibility of bioremediated soil venting of light hydrocarbons in the unsaturated zone was investigated. Degradation mechanics were considered as a one dimensional balance of storage, linear sorption, vertical advection, and Michaelis-Menton kinetics. The resulting analytical solution was tested successfully against field performance data of an unsaturated clay soil bioreactor for a pollpellant waste gas mixture of propane, n-butane, and isobutane. A series of venting simulations was run to assess the biodegradation of vapors above an aviation gasoline spill in sandy soil at Traverse City, Michigan, based on field and microcosm estimates of the kinetic parameters. Acclimated, nutrient rich soil effectively and feasibly reduced effluent vapor concentration from the strong influent concentration associated with dispersed residual gasoline in the contaminated capillary fringe. Aggregated residual contamination required a stronger airflow for a longer duration while natural kinetics were too slow for feasible and effective treatment by bioremediated soil venting at Traverse City.

15D

Bioremediation Case Studies: Abstracts.

Devine, K., U.S. Environmental Protection Agency, Office of Environmental Engineering and Technology Demonstration, Washington, DC, DEVO Enterprises, Inc., Washington, DC, March 1992

EPA Document Number: 600/R-92/044

NTIS Document Number: PB92-232347/XAB

The report contains abstracts of 132 case studies of bioremediation technology applied to hazardous waste clean-up. It was prepared to compile bioremediation studies in a variety of locations and treating diverse contaminants, most of

which were previously undocumented. All data are based on vendor-supplied information and there was no opportunity to independently confirm its accuracy. These 132 case studies, from 10 different biotechnology companies, provide users with reference information about on-going and/or completed field applications and studies. About two-thirds of the cases were at full-scale clean-up level with the remainder at pilot or laboratory scale. In 74% of the cases, soil was at least one of the media treated. Soil alone accounts for 46% of the cases. Petroleum-related wastes account for the largest contaminant with 82 cases. Thirty-one States are represented in the case studies.

16A

Bioremediation Case Studies: An Analysis of Vendor Supplied Data.
Devine, K., Environmental Protection Agency, Office of U.S. Environmental Engineering and Technology Demonstration, Washington, D.C., DEVO Enterprises, Inc., Washington, DC, March 1992

EPA Document Number: 600/R-92/043

NTIS Document Number: PB92-232339/XAB

The report provides users with reference information about 132 on-going and/or completed field applications and studies from 10 different biotechnology companies. About two-thirds of the cases were at full-scale clean-up level with the remainder at pilot or laboratory scale. The report does not contain information from all companies involved in bioremediation, only those companies who responded to a request for voluntary submission.

16B

Bioremediation of Contaminated Surface Soils.
Matthews, J.E.; Sims, J.L.; Sims, R.C.; and Robert S. Kerr Environmental Research Laboratory, Ada, OK, Dynamac Corp., Ada, OK, Utah State University, Logan, UT. Prepared in cooperation with Dynamac Corporation, Ada, OK, and Utah State University, Logan, UT, August 1989

NTIS Document Number: PB90-164047/XAB

Biological processes, including microbial degradation, have been identified as critical mechanisms for attenuating organic contaminants during transit through the vadose zone to the groundwater. On-site soil remedial measures using biological processes can reduce or eliminate groundwater contamination, thus reducing the need for extensive groundwater monitoring and treatment requirements. On-site remedial systems that utilize the soil as the treatment system accomplish treatment by using naturally occurring microorganisms to treat the contaminants. Treatment often may be enhanced by a variety of physical/chemical methods, such as fertilization, tilling, soil pH adjustment, moisture control, etc. The development of a bioremediation program for a specific contaminated soil system includes: (1) a thorough site/soil/waste characterization; (2) treatability studies; and (3) design and implementation of the bioremediation plan. Biological remediation of soils contaminated with organic chemicals has been demonstrated to be an alternative treatment technology that can often meet the goal of achieving a permanent clean-up remedy at hazardous waste sites.

16C

Bioremediation of Explosives.
Alvarez, M.A.; Hanners, J.L.; and Unkefer, P.J.; et al, Los Alamos National Laboratory, Los Alamos, NM, Sponsored by the U.S. Department of Energy, Washington, DC, 1990

NTIS Document Number: DE90-011989/XAB

The extensive manufacture, packing, and the use of explosives has often resulted in significant contamination of soils and groundwaters near these activities. Congressional mandate has now required that such sites be remediated. An especially promising technology for this explosives problem is biotechnology. When applicable, biotechnology is cheap and provides complete conversion of hazardous compounds to harmless biomass or carbon dioxide. The focus of this paper will be on our present understanding of the microbial metabolism of the explosives, TNT and RDX, which have been used most extensively in the United States. To assure that an efficient process is developed for TNT biodegradation, we are conducting appropriate lab scale tests with TNT contaminated soil. First, we are testing their efficiency in soil/water slurries; we are also testing their efficiency in a column system designed to simulate composting conditions. A pilot scale test of this bacterial degradation will be conducted as soon as weather permits.

16D

Bioremediation of Hazardous Wastes.
Biosystems Technology Development Program, Office of Research and Development, U.S. Environmental Protection Agency, Ada, OK; Athens, GA; Cincinnati, OH; Gulf Breeze, FL; and Research Triangle Park, NC, August 1992

EPA Document Number: 600/R-92/126

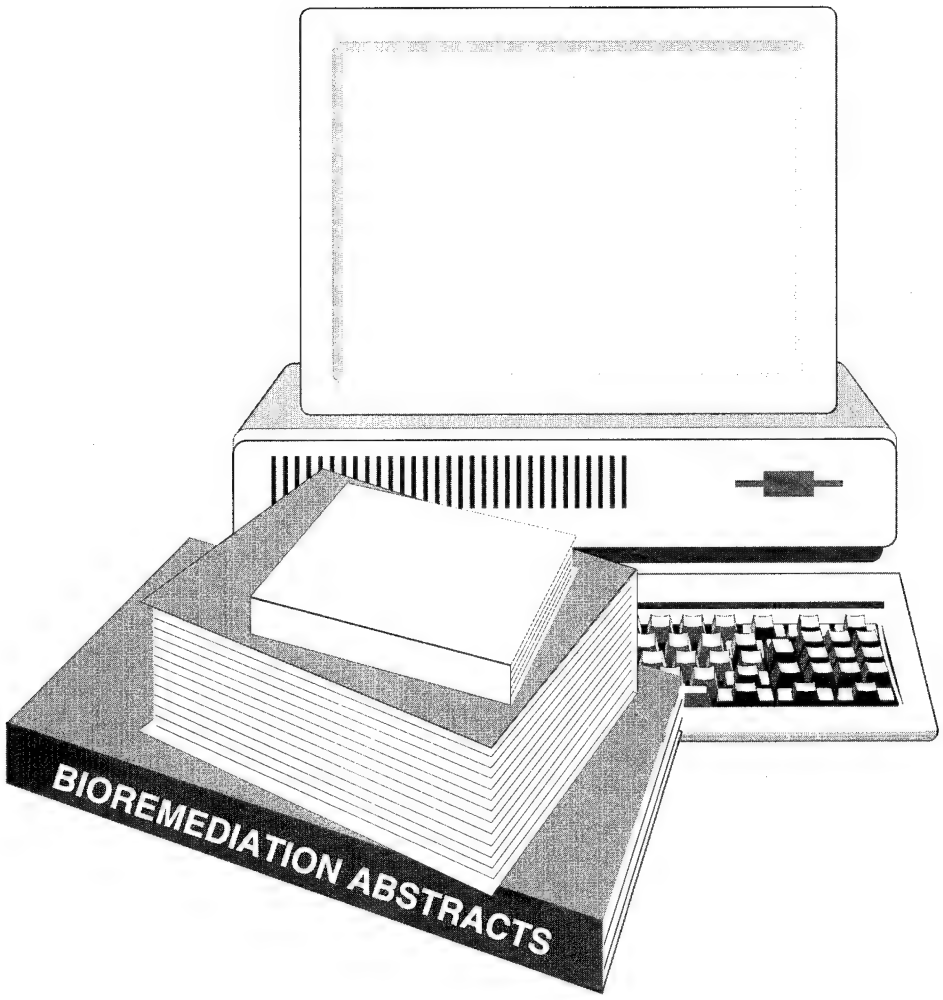
In 1987, the U.S. Environmental Protection Agency's Office of Research and Development (ORD) initiated the Biosystems Technology Development Program to anticipate and address research needs in managing our nation's hazardous waste. This document contains papers and posters presented at the fifth annual Symposium on Bioremediation of Hazardous Wastes: U.S. EPA's Biosystems Technology Development Program held in Chicago in 1992. The five research and program areas

United States
Environmental Protection
Agency

Office of Solid Waste
and Emergency Response
Technology Innovation Office
Washington, DC 20460

EPA/542-B-93-004a
September 1993

EPA Bioremediation Resource Matrix



- Easy to Use Matrix that Assists in Identification of Appropriate Documents
- Descriptions of Bioremediation-Related Databases, Hotlines, Catalogs, and Dockets

BIOREMEDIATION RESOURCE MATRIX

Abstract Identification Code 6 (page #) A (abstract code)	Document Title / Document Ordering Number	TECHNOLOGY TYPE: In-Situ	Slurry Phase	Solid Phase	Land Treatment	MEDIA: Soil/Sludge	Ground Water	CONTAMINANTS: VOCs	Semi-Volatiles	PCBs	Pesticides	PAHs	BTEX	Originating Office/Author
BIBLIOGRAPHIES	**CONTENTS**													
6A	Biodegradation of Pesticides NTIS PB93-854297/XAB										●			NERAC, Inc.
6B	Biodegradation of Toxic Wastes NTIS PB93-851699/LL							●	●				●	NERAC, Inc.
6C	Bioremediation. January 1988 - March 1992 (Citations from NTIS Database) NTIS PB93-868602/LL							●	●	●		●	●	NTIS
6D	Federal Publications on Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: Second Edition EPA/542/B-92/001, NTIS PB93-145696/LL					●	●	●	●		●	●	●	Federal Remediation Technologies Roundtable
7A	Hazardous Materials: Microbiological Decomposition. (Citations from BioBusiness Database) NTIS PB92-853985/XAB							●	●	●	●	●	●	NTIS
7B	Literature Survey of Innovative Technologies for Hazardous Waste Site Remediation (1987-1991) EPA/542/B-92/004, NTIS PB93-105617/XAB					●	●							EPA/OSWER
7C	Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation (A Bibliography of EPA Information Resources) EPA/542/B-93/001					●	●	●					●	EPA
7D	Subsurface Science Program Bibliography (1985-1992) NTIS DE92-040642/XAB							●						DOE/OHER
GUIDANCE/WORKSHOPS	**CONTENTS**													
8A	Bioremediation of Hazardous Waste Sites Workshop NTIS PB89-169205/XAB	●												EPA/CERI
8B	Biotechnology Workgroup for Department of Defense Soil and Groundwater Decontamination Applications NTIS ADA237956/8/XAB					●	●	●	●					Naval Civil Eng. Lab, Life Systems Inc., Reuter
8C	Contaminants and Remedial Options at Wood Preserving Sites NTIS PB92-232222/XAB							●	●			●		Foster Wheeler Enviresponse Selvakumar, Sudeli, Wolf
8D	Environmental Biotechnology of Hazardous Wastes Research Planning Workshop NTIS DE89-001340/XAB	●												Oak Ridge Natl. Lab TN Univ., DOE
9A	Guidance Manual on Hazardous Waste Land Treatment Closure/Post-Closure EPA 68-01-7266, NTIS PB87-183695/XAB				●									Utah State Univ. Sims, Sims
9B	Innovative Technology: Slurry-Phase Biodegradation Fact Sheet NTIS PB90-274200/XAB		●			●		●	●			●		EPA/OERR
9C	Methodologies for Evaluating In-Situ Bioremediation of Chlorinated Solvents EPA/600/R-92/042, NTIS PB92-146943/XAB	●						●	●					Stanford, Robert S. Kerr Lab Grbic- Galic, McCarty, Roberts, Semprini
9D	"No Migration" Variances to the Hazardous Waste Land Disposal Prohibitions: A Guidance Manual for Petitioners EPA/530/SW-90/045, NTIS PB90-204736/XAB			●	●	●								EPA/OSW
9E	Rotating Biological Contactors EPA/540/S-92/007, NTIS PB92-235936/XAB						●		●					EPA/OERR
10A	Slurry Biodegradation Engineering Bulletin EPA 68-C8-0062, NTIS PB91-228049/XAB		●			●								EPA/OERR
OVERVIEW DOCUMENTS	**CONTENTS**													
10B	Bioprocessing Applications in the Management of Nuclear and Chemical Wastes NTIS DE89-003368/XAB													DOE/Oak Ridge Natl. Lab Genung
10C	Bioremediation: An Information Update on Applying Bioremediation to Site Cleanup EPA/540/N-92/001, NTIS PB93-126175/XAB													EPA/OSWER
10D	Critical Review of In-Situ Bioremediation (Topical Report January 1990 - March 1992) NTIS PB93-114247/XAB	●												Illinois Univ. Rittmann, Seagren, Valocchi, Wrenn
11A	Hazardous Waste Land Treatment: A Technology and Regulatory Assessment NTIS DE88-005571/XAB			●		●		●	●					Argonne Natl. Lab Brown, Evans, Overcash
11B	In-Situ/On-Site Biodegradation of Refined Oils and Fuels (A Technology Review) NTIS ADA252681/2/XAB	●	●	●	●	●	●	●	●				●	Naval Civil Eng. Lab Riser-Roberts
11C	Literature Review and Preliminary Assessment of Biological Transformations and Biotreatment Technology for Petroleum													DOE/Oak Ridge Natl. Lab Ayorinde, Reynolds

10A	Slurry Biodegradation Engineering Bulletin EPA 68-C8-0062, NTIS PB91-228049/XAB		●			●									EPA/OERR
OVERVIEW DOCUMENTS															**CONTENTS**
10B	Bioprocessing Applications in the Management of Nuclear and Chemical Wastes NTIS DE89-003368/XAB														DOE/Oak Ridge Natl. Lab Genung
10C	Bioremediation: An Information Update on Applying Bioremediation to Site Cleanup EPA/540/N-92/001, NTIS PB93-126175/XAB														EPA/OSWER
10D	Critical Review of In-Situ Bioremediation (Topical Report January 1990 - March 1992) NTIS PB93-114247/XAB	●													Illinois Univ. Rittmann, Seagren, Valocchi, Wrenn
11A	Hazardous Waste Land Treatment: A Technology and Regulatory Assessment NTIS DE88-005571/XAB			●		●		●	●						Argonne Natl. Lab Brown, Evans, Overcash
11B	In-Situ/On-Site Biodegradation of Refined Oils and Fuels (A Technology Review) NTIS ADA252681/2/XAB	●	●	●	●	●	●	●	●					●	Naval Civil Eng. Lab Riser-Roberts
11C	Literature Review and Preliminary Assessment of Biological Transformations and Biotreatment Technology for Petroleum NTIS ADA219352/2/XAB														DOE/Oak Ridge Natl. Lab Ayorinde, Reynolds
12A	Overview of In-Situ Waste Treatment Technologies NTIS DE92-018012/XAB	●							●						EG&G Idaho Inc. Hyde, Piper, Roy, Walker
12B	Reductive Dehalogenation: A Subsurface Bioremediation Process (Journal Article) NTIS PB91-144873/XAB	●				●	●	●	●			●			Robert S. Kerr Lab, Utah Water Res. Lab, OK Univ., Russell, Sims, Suflita
12C	Reductive Dehalogenation of Organic Contaminants in Soil and Ground Water NTIS PB91-191056/XAB					●	●	●	●			●			Robert S. Kerr Lab Russell, Sims, Suflita
13A	Report on Decontamination of PCB-Bearing Sediments NTIS PB88-113220/XAB					●				●					EPA/Haz. Waste Eng. Lab Wilson
13B	Status of Land Treatment as a Hazardous Waste Management Alternative in the U.S. NTIS PB91-196105/XAB			●	●	●		●						●	EPA/RREL Matthews, McFarland, Sims
13C	Use of Innoculation in Bioremediation EPA/600/J-92/383, NTIS PB93-121150/XAB								●						Env. Research Lab Pritchard
STUDY/TEST RESULTS															**CONTENTS**
13D	Alternative Biological Treatment Processes for Remediation of Creosote- and PCP-Contaminated Materials: Bench-Scale Treatability Studies EPA 68-033479, NTIS PB91-179085/XAB		●	●		●		●	●			●			Southern BioProducts Inc. Blattman, Lantz, Mueller
13E	Approach to Bioremediation of Contaminated Soil (Journal Article) NTIS PB91-116152/XAB					●	●		●						Utah State Univ., Robert S. Kerr Lab Matthews, Sims, Sims
14A	Assessing Detoxification and Degradation of Wood Preserving and Petroleum Wastes in Contaminated Soil (Journal Article) NTIS PB90-245275/XAB	●				●			●			●			Robert S. Kerr Lab, Utah State Univ. Aprill, Sims, Sims
14B	Assessment of Problems Associated with Landfilling or Land Application of Pesticide Waste and Feasibility of Cleanup by Microbial Degradation NTIS PB91-121244/XAB										●				Illinois Univ. Case, Dzantor, Felsot
14C	Biodegradation of Hydrocarbons as a Remediation Method for Petroleum Contaminants in the Environment or as a Treatment Method for Petroleum Wastes. (A Review and Analysis of Recent Field Study Literature) NTIS ADA220718/1/XAB	●	●	●	●	●		●						●	Kansas Univ. Lubbers
15A	Biodegradation of JP-5 Aviation Fuel by Subsurface Microbial Communities NTIS ADA192743/3/XAB					●		●	●					●	Naval Engineering Lab Swindoll
15B	Biological Treatment of Soils Containing Manufactured Gas Plant Residues NTIS PB90-259961/XAB					●			●			●			Remediation Technologies Cushey, Morgan, Morgan
15C	Bioremediated Soil Venting of Light Hydrocarbons (Journal Article) NTIS PB91-171538/XAB	●						●						●	Univ. of MA Kampbell, Ostendorf
15D	Bioremediation Case Studies: Abstracts EPA/600/R-92/044, NTIS PB92-232347/XAB							●						●	EPA/OEETD, DEVO Devine
16A	Bioremediation Case Studies: An Analysis of Vendor Supplied Data EPA/600/R-92/043, NTIS PB92-232339/XAB														EPA/OEETD, DEVO Devine
16B	Bioremediation of Contaminated Surface Soils NTIS PB90-164047/XAB					●									Robert S. Kerr Lab, Dynamic Corp, UT State Univ., Matthews, Sims, Sims
16C	Bioremediation of Explosives NTIS DE90-011989/XAB					●	●		●						Los Alamos Natl. Lab Alvarez, Hanners, Unkefer
16D	Bioremediation of Hazardous Wastes EPA/600/R-92/126	●	●	●	●	●	●	●	●	●		●	●		EPA/ORD
17A	Bioremediation of PCB-Contaminated Soil at the Y-12 Plant NTIS DE89-001335/XAB	●	●			●			●	●					DOE/Oak Ridge Natl. Lab Donaldson, McGinnis, Strandberg
17B	Bioremediation of Polychlorinated Phenyls: Degradation Capabilities in Field Lysimeters NTIS DE89-000451/XAB					●			●	●					DOE/Oak Ridge Natl. Lab Hill, Palumbo, Phelps
17C	Bioventing Approach to Remediate a Gasoline Contaminated Subsurface EPA/600/A-92/220, NTIS PB93-119816/XAB	●						●						●	Traverse Group, Inc. Griffin, Kampbell, Wilson
17D	Cometabolic Biotreatment of TCE-Contaminated Ground Water: Laboratory and Bench Scale Development Studies NTIS DE92-007252/XAB						●		●						DOE/Oak Ridge Natl. Lab Donaldson, Jennings, Lucero, Morris, Strandberg
18A	Creosote Contaminated Sites: Their Potential for Bioremediation (Journal Article) NTIS PB90-129552/LL							●	●						Envir. Research Lab Chapman, Mueller, Pritchard

	NTIS PB90-164047/XAB						●								UT State Univ., Matthews, Sims, Sims
16C	Bioremediation of Explosives NTIS DE90-011989/XAB						●	●		●					Los Alamos Natl. Lab Alvarez, Hanners, Unkefer
16D	Bioremediation of Hazardous Wastes EPA/600/R-92/126	●	●	●	●		●	●		●	●		●	●	EPA/ORD
17A	Bioremediation of PCB-Contaminated Soil at the Y-12 Plant NTIS DE89-001335/XAB	●	●				●			●	●				DOE/Oak Ridge Natl. Lab Donaldson, McGinnis, Strandberg
17B	Bioremediation of Polychlorinated Phenyls: Degradation Capabilities in Field Lysimeters NTIS DE89-000451/XAB						●			●	●				DOE/Oak Ridge Natl. Lab Hill, Palumbo, Phelps
17C	Bioventing Approach to Remediate a Gasoline Contaminated Subsurface EPA/600/A-92/220, NTIS PB93-119816/XAB	●							●					●	Traverse Group, Inc. Griffin, Kampbell, Wilson
17D	Cometabolic Biotreatment of TCE-Contaminated Ground Water: Laboratory and Bench Scale Development Studies NTIS DE92-007252/XAB							●		●					DOE/Oak Ridge Natl. Lab Donaldson, Jennings, Lucero, Morris, Strandberg
18A	Creosote Contaminated Sites: Their Potential for Bioremediation (Journal Article) NTIS PB90-129552/LL								●	●					Envir. Research Lab Chapman, Mueller, Pritchard
18B	Degradation of Hazardous Organic Wastes by Microorganisms NTIS ADA196671/LL						●	●		●			●		Naval Ocean Systems Center Kenis
18C	Development of Water and Soil Treatment Technology Based on the Utilization of a White-Rot, Wood Rotting Fungus NTIS PB88-238175/LL								●	●	●	●			EPA/Haz. Waste Eng. Res. Lab Glaser
18D	Enhanced Bioreclamation of Jet Fuels: A Full Scale Test at Eglin A.F.B., Florida (Final Report November 1986 - 1988) NTIS ADA222348/5/XAB						●	●	●					●	Eng., Science, & Tech, Inc. Downey, Hinchee, Slaughter
18E	Enhanced Bioremediation Utilizing Hydrogen Peroxide as a Supplemental Source of Oxygen: A Laboratory and Field Study EPA/600/15, NTIS PB90-183435/AS	●						●	●	●				●	EPA/Robert S. Kerr Lab. Bledsoe, Huling, White
19A	Evaluation of the Bioremediation of a Contaminated Soil with Phytotoxicity Tests (Journal Article) EPA/600/J-93/166, NTIS PB93-191625			●			●						●		EPA/RREL, T&E Facility, ITC Baud-Grasset, Baud-Grasset, Safferman
19B	Feasibility of Biodegrading TNT - Contaminated Soils in a Slurry Reactor - Progress Report (Final Report) NTIS DE91-008036/XAB		●				●			●					Argonne Natl. Lab Irvine, Montemagno
19C	Feasibility of Coal Tar Biodegradation by Land Treatment: (Final Report) NTIS PB91-102368/XAB				●		●			●			●		Cambridge Anal. Assoc., Inc. Fogel
20A	Field Evaluation of In-Situ Biodegradation of Chlorinated Ethenes (Journal Article) NTIS PB91-144857/XAB	●						●	●						Stanford Univ. Hopkins, Mackay, Roberts
20B	Field Scale Investigation of Enhanced Petroleum Hydrocarbon Biodegradation in the Vadose Zone Combining Soil Venting as an Oxygen Source with Moisture and Nutrient Addition (Doctoral Thesis) NTIS ADA227981/8/XAB	●		●			●		●					●	Air Force Instit. of Tech. Miller
20C	Fungal Degradation of Organophosphorous Insecticides NTIS DE92-016191/XAB											●			Argonne Natl. Lab Bumpus, Coleman, Kakar
20D	In-Situ Biodegradation of Nitroaromatic Compounds in Soil NTIS ADA254120/9/XAB	●					●			●					Idaho University Crawford
20E	In-Situ Biological Treatment Test at Kelly Air Force Base, Volume 2, Field Test Results and Cost Model NTIS ADA203213/4/XAB	●					●	●		●					SAIC Davidson, Durst,Wetzel
21A	In-Situ Biorestoration of a Subsoil Contaminated with Gasoline (Interim Report) NTIS PB90-247727/XAB	●						●	●					●	Rijksinstituut voor de Volksgezondheid en Milieuhygiene Eikelboom van den Berg, Verheul
21B	Installation Restoration Prog.: Env. Tech. Dev. Field Demo. - Composting of Explosives- Contaminated Sediments at LAAP NTIS ADA202383/6/XAB			●	●		●		●	●					Weston Inc. Marks, Williams, Ziegenfus
21C	Metabolism of Chlorinated Methanes, Ethanes, and Ethylenes by a Mixed Bacterial Culture Growing on Methane (Journal Article) EPA R-812220, NTIS PB91-144774/XAB						●		●	●					RMT Inc., CA Univ., IL DNR, Northrop Services, Robert S. Kerr Lab Cochran, Henson, Yates
22A	Microbial Degradation of Toluene Under Sulfate - Reducing Conditions and the Influence of Iron on the Process EPA/600/J-92/139, NTIS PB92-166735/XAB								●	●					Stanford Univ./Robert S. Kerr Lab Beller, Grbic-Galic, Reinhard
22B	On-Site Treatment of Creosote and Pentachlorophenal Sludges and Contaminated Soil Research Report NTIS PB91-223370/XAB								●	●			●		MS Forest Products Lab, Robert S. Kerr Lab, Borazjani, McGinnis, Pope
22C	Preliminary Feasibility and Cost Analysis of the In-Situ Microbial Filter EPA R-812220, NTIS DE92-018662/XAB							●	●						Lawrence Livermore Natl. Lab Carman, Knapp, Taylor, Wijen singhe
23A	Process and Economic Feasibility of Using Composting Technology to Treat Waste Nitrocellulose Fines NTIS ADA241033/0/XAB		●	●	●		●								TVA Breed, Crim, McGill
23B	Removal of Volatile Aliphatic Hydrocarbons in Soil Bioreactor (Journal Article) NTIS PB88-180393/XAB		●				●		●					●	Robert S. Kerr Lab, Johnson and Son, Inc., Kampbell, Read, Wilson
23C	Soil Bioventing Demonstration Project NTIS PB91-162628/XAB	●					●		●					●	New Jersey Inst. of Tech., Robert S. Kerr Lab, Cho, Kampbell, Wilson
24A	TCE Removal from Contaminated Soil and Ground Water. Ground Water Issue EPA/540/S-92/002, NTIS PB92-224104/XAB		●				●	●	●						EPA/OSWER Matthews, Russell, Sewell
24B	Treatment of Chlorophenol Contaminated Water and Soils Using Immobilized Microorganisms NTIS PB90-222241/XAB				●		●	●		●					BioTrol, Inc. Chresand, Crawford
24C	Treatment Potential for 56 EPA Listed Hazardous Chemicals in Soil EPA R-810979, NTIS PB88-174446/XAB						●		●	●		●	●		Utah State Univ., Robert S. Kerr Lab Doucette, McLean, Sims

24D	A Field Evaluation of In-Situ Bioremediation for Aquifer Restoration EPA 600/15, NTIS PB88-130257/AS	●						●		●					Stanford Univ. Hopkins, Mackay,Roberts, Semprini

	NTIS PB91-102368/XAB														Fogel
20A	Field Evaluation of In-Situ Biodegradation of Chlorinated Ethenes (Journal Article) NTIS PB91-144857/XAB	●					●	●							Stanford Univ. Hopkins, Mackay, Roberts
20B	Field Scale Investigation of Enhanced Petroleum Hydrocarbon Biodegradation in the Vadose Zone Combining Soil Venting as an Oxygen Source with Moisture and Nutrient Addition (Doctoral Thesis) NTIS ADA227981/8/XAB	●		●		●		●					●		Air Force Instit. of Tech. Miller
20C	Fungal Degradation of Organophosphorous Insecticides NTIS DE92-016191/XAB										●				Argonne Natl. Lab Bumpus, Coleman, Kakar
20D	In-Situ Biodegradation of Nitroaromatic Compounds in Soil NTIS ADA254120/9/XAB	●				●			●						Idaho University Crawford
20E	In-Situ Biological Treatment Test at Kelly Air Force Base, Volume 2, Field Test Results and Cost Model NTIS ADA203213/4/XAB	●				●	●		●						SAIC Davidson, Durst,Wetzel
21A	In-Situ Biorestoration of a Subsoil Contaminated with Gasoline (Interim Report) NTIS PB90-247727/XAB	●					●	●						●	Rijksinstituut voor de Volksgezondheid en Milieuhygiene Eikelboom van den Berg, Verheul
21B	Installation Restoration Prog.: Env. Tech. Dev. Field Demo. - Composting of Explosives- Contaminated Sediments at LAAP NTIS ADA202383/6/XAB			●	●	●		●	●						Weston Inc. Marks, Williams, Ziegenfus
21C	Metabolism of Chlorinated Methanes, Ethanes, and Ethylenes by a Mixed Bacterial Culture Growing on Methane (Journal Article) EPA R-812220, NTIS PB91-144774/XAB					●		●	●						RMT Inc., CA Univ., IL DNR, Northrop Services, Robert S. Kerr Lab Cochran, Henson, Yates
22A	Microbial Degradation of Toluene Under Sulfate - Reducing Conditions and the Influence of Iron on the Process EPA/600/J-92/139, NTIS PB92-166735/XAB							●	●						Stanford Univ./Robert S. Kerr Lab Beller, Grbic-Galic, Reinhard
22B	On-Site Treatment of Creosote and Pentachlorophenal Sludges and Contaminated Soil Research Report NTIS PB91-223370/XAB							●	●			●			MS Forest Products Lab, Robert S. Kerr Lab, Borazjani, McGinnis, Pope
22C	Preliminary Feasibility and Cost Analysis of the In-Situ Microbial Filter EPA R-812220, NTIS DE92-018662/XAB						●	●							Lawrence Livermore Natl. Lab Carman, Knapp, Taylor, Wijen singhe
23A	Process and Economic Feasibility of Using Composting Technology to Treat Waste Nitrocellulose Fines NTIS ADA241033/0/XAB		●	●	●	●									TVA Breed, Crim, McGill
23B	Removal of Volatile Aliphatic Hydrocarbons in Soil Bioreactor (Journal Article) NTIS PB88-180393/XAB		●			●		●						●	Robert S. Kerr Lab, Johnson and Son, Inc., Kampbell, Read, Wilson
23C	Soil Bioventing Demonstration Project NTIS PB91-162628/XAB	●				●		●						●	New Jersey Inst. of Tech., Robert S. Kerr Lab, Cho, Kampbell, Wilson
24A	TCE Removal from Contaminated Soil and Ground Water. Ground Water Issue EPA/540/S-92/002, NTIS PB92-224104/XAB		●			●	●	●							EPA/OSWER Matthews, Russell, Sewell
24B	Treatment of Chlorophenol Contaminated Water and Soils Using Immobilized Microorganisms NTIS PB90-222241/XAB				●	●	●		●						BioTrol, Inc. Chresand, Crawford
24C	Treatment Potential for 56 EPA Listed Hazardous Chemicals in Soil EPA R-810979, NTIS PB88-174446/XAB					●		●	●		●	●			Utah State Univ., Robert S. Kerr Lab Doucette, McLean, Sims
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24D	A Field Evaluation of In-Situ Bioremediation for Aquifer Restoration EPA 600/15, NTIS PB88-130257/AS	●					●		●						Stanford Univ. Hopkins, Mackay,Roberts, Semprini
25A	Biological Remediation of Contaminated Soils at Los Angeles A.F.B.: Facility Design and Engineering Cost Estimate NTIS DE91-006975/LL		●			●		●	●					●	Argonne Natl. Lab Irvine, Montemagno
25B	In-Situ Bioremediation of Contaminated Groundwater EPA/540/5-92/003, NTIS PB92-224336/XAB	●					●								EPA/OSWER Russell, Sims, Suflita
25C	Microbial Decomposition of Chlorinated Aromatic Compounds EPA/600/2-86/090, NTIS PB87-116943/LL	●	●				●	●	●	●	●			●	IT Corp., EPA/Haz. Waste Eng. Res. Lab, Blackburn, Rochkind
25D	Treatability and Scale-Up Protocols for Polynuclear Aromatic Hydrocarbon Bioremediation of Manufactured Gas Plant Soils (Final Report) NTIS PB91-240713/XAB					●			●			●			TN Univ., Gas Research Inst. Blackburn, Digrazia, Sandevering
EXAMPLES OF OTHER RELEVANT DOCUMENTS															**CONTENTS**
26A	Biodegradation of Volatile Organic Chemicals in a Biofilter *American Chemical Society Symposium 468*	Biofilter				Surface Water		●							Univ. of Cincinnati, EPA/RREL Brenner, Govind, Safferman, Shan, Utgikar
26B	Treatment of CERCLA Leachates by Carbon-Assisted Anaerobic Fluidized Beds (Journal Article) *Water Science Technology*, v27n2, 1993	Bioreactor				Surface Water		●	●						Univ. of Cincinnati, ITEP, EPA Brenner, Krishnan, Nath, Schroeder, Suidan
26C	Treatment of VOCs in High Strength Wastes Using An Anaerobic Expanded-Bed GAC Reactor (Journal Article) *Water Research*, v27n1, 1993	Bioreactor				Surface Water		●							John Carollo Eng., Univ. of Cincinnati, Malcom Pirnie, EPA Brenner, Gelderloos, Narayanan, Suidan

1 Note: This matrix provides representative examples of bioremediation resource documents. It is not all inclusive. Those seeking information on oil spills, waste minimization, natural biodegradation, or leaching/immobilization may wish to contact the hotlines, dockets, etc. listed on the back of this document.

2 Note: We acknowledge that many other helpful resources are available. Therefore, samples of documents relevant to ex-situ bioremediation using a biofilter and bioremediation in other media (e.g., surface water) are included.

3 Note: BTEX is included as a separate contaminant category at the request of the Underground Storage Tank Program.

4 Note: An absence of bullets describing a document's content indicates that the document is general.

SOURCES OF BIOREMEDIATION INFORMATION/ TECHNICAL ASSISTANCE

Numerous computer-based bulletin boards, regulatory hotlines, dockets, databases, catalogs, and periodicals are also available. These resources provide technical information on bioremediation and other innovative technologies and guide you to additional valuable resources.

BULLETIN BOARDS:

- **Alternative Treatment Technologies Information Center (ATTIC) (data line) 301-670-3808**
  To obtain information on ATTIC 908-906-6828
  A collection of hazardous waste databases accessed through a bulletin board that provides hazardous waste abstracts, news bulletins, conference information, and a message board.

- **Cleanup Information Bulletin (CLU-IN) (data line).....301-589-8366**
  A bulletin board for hazardous waste professionals that provides current information on innovative technologies. Provides information bulletins, message and on-file exchange, and on-line databases and directories.

  Help Line 301-589-8368
  Addresses questions about CLU-IN access and contents; addresses problems with the service.

- **Office of Research and Development (ORD) (data line) 800-258-9605**
  Bulletin Board Service (BBS) (data line) 513-569-7610
  Provides a bibliography of 18,000 documents, news excerpts from "Bioremediation in the Field," and a message board.

  Help Line 513-569-7272
  Provides information on access to and contents of the ORD BBS.

CATALOGS:

- **Catalog of Hazardous and Solid Waste Publications, *Sixth Edition*** *EPA/530-B-92-001*
  Catalogs Office of Solid Waste policy directives, guidance documents, brochures, Regulatory Development Branch memos, and other documents relevant to hazardous and solid waste.

- **Compendium of Superfund Program Publications**
  EPA/540/8-91/014, NTIS PR 881
  Provides abstracts and ordering information for fact sheets, directives, publications, and computer materials on Superfund. Use the document ordering directions to compendium.

DATABASES:

- **DIALOG Database 800-3-DIALOG**
  A large database that contains files relevant to hazardous waste including: Biotechnology Abstracts; Enviroline; Corrective Action Search; Pollution Abstracts; National Technical Information Services (NTIS); and others.

- **NTIS Database**
  Contains abstracts of government-sponsored research, development, and engineering analyses prepared by approximately 250 Federal agencies and some State and local governments. Accessible via the DIALOG system.

- **Records of Decision System (RODS)**
  (To get information on accessing RODs).....703-603-8881
  Contains the full text of all signed Records of Decision for hazardous waste clean-up sites nationwide. Direct access to RODS is available to EPA personnel and organizations that have relevant EPA contracts.

- **Vendor Information System for Innovative Treatment Technologies (VISITT) 800-245-4505**
  Contains current information on availability, performance, and cost of innovative technologies to remedy hazardous waste sites.

DOCKETS:

- **Federal Facilities Docket Hotline 800-548-1016**
  Provides the name, address, NPL status, agency, and Region for the 1,930 Federal facilities listed on the Federal Facilities Docket. Facilities are on the docket because they reported being a RCRA TSDF or having spilled or having the potential to release CERCLA hazardous waste. Operates Monday - Friday, 8 a.m. - 6 p.m., Eastern Time.

- **RCRA Information Center 202-260-9327**
  Indexes and provides public access to all regulatory materials supporting the Agency's actions under RCRA, and disseminates current Office of Solid Waste publications. Operates Monday - Friday, 8:30 a.m. - 4 p.m., Eastern Time.

- **Superfund Docket 202-260-3046**
  Provides access to Superfund regulatory documents, Superfund Federal Register Notices, and Records of Decision. Operates Monday - Friday, 9 a.m. - 4 p.m., Eastern Time.

- **UST Docket 202-260-9720**
  Provides documents and regulatory information pertinent to RCRA's Subtitle I (the Underground Storage Tank program). *Operates Monday - Friday, 9 a.m. - 4 p.m., Eastern Time.*

HOTLINES/REGULATORY/TECHNICAL ASSISTANCE:

- **EPA Headquarters Library 202-260-5921**
  Offers reports from various EPA offices and trade and environmental journals. Features the "Hazardous Waste Collection" department. Operates Monday - Friday, 10 a.m. - 4 p.m., Eastern Time.

- **RCRA/Superfund/UST Hotline 800-424-9346**
  Provides regulatory assistance related to RCRA, CERCLA, and UST programs. Serves as a liaison between the regulated community and EPA personnel and provides information on the availability of relevant documents. Operates Monday - Friday, 8:30 a.m. - 7:30 p.m., Eastern Time.

- **TSCA Hotline 202-554-1404**
  Answers public and private regulatory questions on TSCA. Refers callers to appropriate EPA contacts, and takes TSCA-relevant document orders. Operates Monday - Friday, 8:30 a.m. - 5 p.m., Eastern Time.

- **Superfund Health Risk Technical Support Center 513-569-7300**
  Provides EPA Regional Superfund risk assessors, State agencies, and those working under EPA contract with technical, typically chemical-specific, support and risk assessment review. Operates Monday - Friday 8 a.m. - 5 p.m., Eastern Time.

INFORMATION CENTER:

- **National Center for Environmental Publications and Information (NCEPI) 513-891-6561**
  (Fax requests) 513-891-6685
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INTRODUCTION

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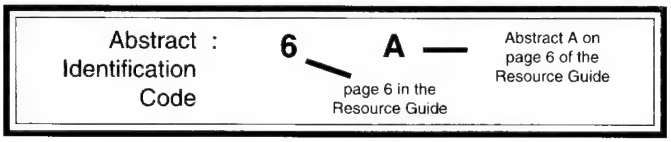

Information contained in this Guide is not intended to be all-inclusive, nor does it represent an endorsement by EPA. In an effort to limit the number of resources listed here, documents on oil spills, waste minimization, natural process bioremediation, leaching/immobilization, and ex-situ aqueous bioremediation, and other media (e.g., air and surface water), as well as Records of Decision and proceedings are not included. Samples of documents focused on ex-situ bioremediation of wastewater and leachate using a biofilter and a bioreactor are included in the matrix. However, those seeking information on these topics or other topics not addressed in this matrix may wish to contact the hotlines, dockets, etc. listed on the adjacent panel.

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addressed by the inclusions in this document are: Site characterization; Bioremediation Field Initiative; Performance Evaluation; Process Research; and Modeling.

17A

Bioremediation of PCB-Contaminated Soil at the Y-12 Plant.

Donaldson, T.L.; McGinnis, G.P.; and Strandberg, G.W.; et al, Oak Ridge National Laboratory, TN, U.S. Department of Energy, Washington, DC, September 1988

NTIS Document Number: DE89-001335/XAB

The technical feasibility of bioremediation of soils contaminated with polychlorinated biphenyls (PCBs) was investigated using six in-situ lysimeters and two slurry bioreactors during the summer and fall of 1987. Microbial degradation of PCBs was characterized, and microbial cultures were isolated and characterized. Indigenous microorganisms present in contaminated soils from the floodplain of Bear Creek were shown to be capable of degrading monochlorinated biphenyl. Evidence included production of radiolabeled carbon dioxide from radiolabeled substrate and microbial characterization using gene probes and signature lipid analyses. Evidence was also obtained for dechlorination of highly chlorinated PCBs under laboratory conditions by microbial cultures isolated from other contaminated soils. These results are quite encouraging for further development of bioremediation technologies for PCBs. In-situ treatment of the soils in lysimeters by aeration/mixing and water appeared to stimulate growth of microorganisms and increase the biodegradation of monochlorinated biphenyl in laboratory experiments using soil samples from the lysimeters. The effects of additional nutrients, carbon sources, and inocula were unclear from these tests; only one condition for each parameter was tested in the limited number of lysimeters.

17B

Bioremediation of Polychlorinated Biphenyls: Degradation Capabilities in Field Lysimeters.

Hill, D.L.; Palumbo, A.V.; and Phelps, T.J.; et al, Oak Ridge National Laboratory, TN, U.S. Department of Energy, Washington, DC, May 1988

NTIS Document Number: DE89-000451/XAB

The degradation of 4-chlorobiphenyl (4CB) was compared in field lysimeters containing 60 Kg of soil contaminated with 5-10 mg/Kg of polychlorinated biphenyls. Alcaligenes A5, a bacterium carrying a plasmid for 4CB degradation, was inoculated into three lysimeters. When compared to an untreated control, soil samples from water, mineral and yeast extract treated lysimeters with and with out a bacterial inoculim exhibited greater than TO fold increases in the rate of (1-(sup 14))C-acetate incorporation into lipids and (sup 14)CO(sub 2) production from (U-(sup 14)C-)4-chlorobiphenyl. Gene probe analyses for the 4CB plasmid and most-probable number enumerations demonstrated the presence of biodegradative populations in lysimeters and the probable survival of the added Alcaligenes A5.

17C

Bioventing Approach to Remediate a Gasoline Contaminated Subsurface, (Book Chapter).

Griffin, C.J., Kampbell, D.H.; and Wilson, J.T., Traverse Group, Inc., Traverse City, MI, 1992

EPA Document Number: 600/A-92/220

NTIS Document Number: PB93-119816/XAB

Bioventing is a subsurface process using an air stream to enhance biodegradation of oily contaminants. Two pilot-scale bioventing systems were installed at a field site. Process operations began in October 1990. The field site is located at an air station. A spill in 1969 of about 100,000 kilograms of aviation gasoline was caused by a broken underground transfer line. A major portion of the spilled product still persists as an oily-phase residue in a 80x360 meter plume. The subsurface is a uniform beach sand with the ground water level near five meters. Prior to startup of the venting systems, a grass cover was established and a nutrient solution was dispersed throughout the unsaturated subsurface. Subsurface air flow patterns are being determined with a tracer gas of sulfur hexafloride. Soil gas, core material, and underground water are being monitored to determine the extent of remediation. Objectives of the study are to demonstrate that surface emissions of gasoline are minimal, oily residue will be reduced to <100 mg fuel carbon/Kg core material, and the process will be applicable to full-scale remediation. Flow rate is based on a calculated residence time of 24 hours. Surface emission of fuel hydrocarbons have not exceeded 1 micrograms/liter soil gas.

17D

Cometabolic Biotreatment of TCE-Contaminated Groundwater: Laboratory and Bench-Scale Development Studies.

Donaldson, T.L.; Jennings, H.L.; Lucero, A.J.; Morris, M.I.; and Strandberg, G.W., Oak Ridge National Laboratory, Oak Ridge, TN, U.S. Department of Energy, Washington, DC, March 1992

NTIS Document Number: DE92-007252/XAB

The Oak Ridge National Laboratory is conducting a demonstration of two cometabolic technologies for biotreatment of groundwater contaminated with trichloroethylene (TCE) and other organics. Technologies based on methanotrophic (methane-utilizing) and toluene-degrading microorganisms will be com-

pared side-by-side on the same groundwater stream. Laboratory and bench-scale bioreactor studies have been conducted to guide selection of microbial cultures and operating conditions for the field demonstration. This report presents the results of the laboratory and bench-scale studies for the methanotrophic system.

18A

Creosote-Contaminated Sites: Their Potential for Bioremediation, Journal Article: Published in *Environmental Science and Technology*, v3n10, October 1989.
Chapman, P.J.; Mueller, J.G.; and Pritchard, Ph.; U.S. Environmental Research Laboratory, Gulf Breeze, FL, 1989

NTIS Document Number: PB90-129552/LL

Bioremediation of creosote-contaminated materials is reviewed here by characterizing coal-tar creosote, identifying techniques for assessing the biodegradability of its many chemical constituents, examining known routes of microbial transformation of these chemicals, and reviewing the performance of previous bioremediation efforts. The approach is developed as a model system to project the potential application of bioremediation to ameliorate environments contaminated by complex mixtures of structurally diverse hazardous chemicals.

18B

Degradation of Hazardous Organic Wastes by Microorganisms Preliminary Report.
Kenis, P., Naval Ocean Systems Center, San Diego, CA, May 1988

NTIS Document Number: ADA196671/LL

This report addresses the microbiological detoxification of hazardous organic compounds before and after they have contaminated soil, groundwater, and other areas. The in-situ degradation of toxic organic compounds is often the most cost-effective cleanup approach. Companies that use or provide microorganisms and other products and services for hazardous organic waste detoxification are listed in the appendices of this report.

18C

Development of Water and Soil Treatment Technology Based on the Utilization of a White-Rot, Wood Rotting Fungus.
Glaser, J.A., U.S. Environmental Protection Agency, Cincinnati, OH, Hazardous Waste Engineering Research Laboratory, August 1988

NTIS Document Number: PB88-238175/LL

The wood rotting fungus, Phanerochaete chrysosporium, has been selected as a candidate species to be used as a degrader of hazardous waste organic constituents found in liquids and soils. The selection of the species is attributable to its rapid growth, its ability to degrade lignin rapidly, its ability to asexually multiply, and its high temperature optimum. Based on the fungus' ability to degrade lignin, several investigators speculated that the fungus should be able to degrade aromatic organic constituents found in hazardous waste. Early studies with the polychlorinated biphenyl mixture Arochlor 1254, DDT, lindane and other chlorinated contaminants indicated that the fungus may have exceptional degradative abilities. The lignin degrading ability of the fungus is a secondary metabolic cycle that is controlled by the absence of certain nutrients.

18D

Enhanced Bioreclamation of Jet Fuels: A Full-Scale Test at Eglin A.F.B., Florida, Final Report November 1986 - November 1988.
Downey D.C.; Hinchee, R.E.; and Slaughter, J.K.; et al, Engineering, Science, and Technology, Inc., Lafayette, CA, U.S. Air Force Engineering and Services Center, Tyndall AFB, FL, Engineering and Services Laboratory, September 1989

NTIS Document Number: ADA222348/5/XAB

This report presents the results of a two-year, full-scale field test of enhanced biodegration conducted at a JP-4 jet fuel spill site on Eglin AFB, FL. A complete description of site characterization methods, the enhanced biodegradation process and hardware, and the impact of this technology on soil and groundwater contaminants is provided. The report emphasizes the treatment limitations of this technology that were observed through intense monitoring of soil and groundwater contaminant profiles. This rapid decomposition resulted in poor oxygen distribution and biodegradation rates that were far less than laboratory microcosm studies had predicted. Several recommendations for improving field applications of enhanced biodegradation are provided, including a checklist for performing pilot tests of this technology.

18E

Enhanced Bioremediation Utilizing Hydrogen Peroxide as a Supplemental Source of Oxygen: A Laboratory and Field Study.
Bledsoe, Bert E.; Huling, Scott G.; and White, Mark V., Robert S. Kerr Environmental Research Laboratory, U.S. Environmental Protection Agency, Ada, OK, NSI Technology Services, Inc., Ada, OK, February 1990

EPA Document Number: 600/15

NTIS Document Number: PB90-183435/AS

Laboratory and field scale studies were conducted to investigate the feasibility of using hydrogen peroxide as a supplemental source of oxygen for bioremediation of an aviation gasoline fuel spill. Field samples of aviation gasoline contaminated aquifer material were artificially enhanced with nutrients to promote microbiological degradation of fuel carbon in a laboratory column experiment. The rapid rate of hydrogen peroxide decomposition at 100.0 mg/1 resulted in the production of oxygen gas. An oxygen mass balance indicated that approximately 44.0% and 45.0% of the influent oxygen was recovered in aqueous and gaseous phases respectively. Reduced rates of oxygen consumption during this period indicated that microbial inhibition may have occurred. A mass balance of the fuel carbon indicated that approximately 36% of the initial mass leached out in aqueous phase, 10.0% remained, and 54.0% degraded. The ratio of oxygen consumed to aviation gasoline degraded was greater than that predicated by the ideal stoichiometric conversion. Hydrogen peroxide breakthrough in the column effluent never exceeded 11.0% of the influent concentration. Groundwater data from the enhanced in-situ bioremediation pilot field study indicates that hydrogen peroxide successfully increased the concentration of available oxygen down-gradient. In this study, however, it was observed that there was a measurable increase of oxygen in the soil gas area where hydrogen peroxide was injected. This indicated that a significant fraction of hydrogen peroxide rapidly decomposed to oxygen gas and escaped into the unsaturated zone.

19A

Evaluation of the Bioremediation of a Contaminated Soil with Phytotoxicity Tests, Journal Article: Published in *Chemosphere*, v26n7, 1993.

Baud-Grasset, Frederic; Baud-Grasset, Sandvine; Safferman, Steven, I, Risk Reduction Engineering Laboratory, U.S. Environmental Protection Agency, Cincinnati, OH, International Technologies Corporation, U.S. Environmental Protection Agency Test and Evaluation Facility, Cincinnati, OH, 1993

EPA Document Number: 600/J-93/166

NTIS Document Number: PB93-191625

The fungal remediation of polycyclic aromatic hydrocarbons in contaminated soil from a hazardous waste site was evaluated in a pilot-scale treatability study. Higher plants were selected to evaluate the overall reduction in toxicity in the soil after fungal treatment because toxicity of a complex chemical mixture often is not easily measured by chemical analyses and disappearance of parent compounds may not indicate detoxification of the soil. Seed germination tests using soil samples and root elongation tests using soil eluates were conducted with three different species (lettuce, oat, and millet) before and after treatment. Phytotoxicity tests revealed significant detoxification of the soil after treatment with a good correlation with parent compound depletion. The seed germination test appeared to be more sensitive than the root elongation test, suggesting that the toxic compounds were not easily extracted from the soil to the aqueous solution. This study indicates that phytotoxicity tests have good potential to be used as an environmental tool to assess the efficacy of a remediation technology for site clean-up.

19B

Feasibility of Biodegrading TNT-Contaminated Soils in a Slurry Reactor. Progress Report, Final Report.

Irvine, R.L. and Montemagno, C.D., Argonne National Laboratory, IL, Sponsored by the U.S. Department of Energy, Washington, DC, June 1990

NTIS Document Number: DE91-008036/XAB

This report presents the results of a study of the feasibility of treating explosives-contaminated soils through biodegradation by bacteria. Soil samples were collected from the Joliet Army Ammunition Plant, and a bacterial consortium tolerant to trinitrotoluene (TNT) was isolated for bench-scale testing in a soil-slurry reaction system. Initial experiments indicated that the consortium can use TNT as a source of carbon, nitrogen, or both. Additional experiments determined system conditions (e.g., type and quantity of nutrients) that enhanced TNT consumption by the consortium. The study results indicate that a soil-slurry/sequencing-batch reactor merits testing as an on-site, pilot-scale system. This report also presents a pilot-scale design and cost analysis.

19C

Feasibility of Coal Tar Biodegradation by Land Treatment, Final Report.

Fogel, S., Cambridge Analytical Associates, Inc., Boston, MA, Bioremediation Systems Division, Sponsored by the National Science Foundation, Washington, DC, September 1987

NTIS Document Number: PB91-102368/XAB

Coal tar, a by-product of coal gasification, contains monoaromatic and polycyclic aromatic hydrocarbons (PAH), which have been identified as carcinogens. Billions of gallons of this waste have been disposed of at numerous gas manufacturing facilities in the United States. The treatment of tar-contaminated soil by bacterial degradation has shown great promise, since one-, two-, and three-ring PAH can be readily degraded by bacteria. Research was carried out to establish whether 4- and 5-ring PAH could also be degraded by bacteria. The data indicated that 4-ring PAH could degrade when dis-

solved in a hydrocarbon carrier or when applied to soil as a component of coal tar. Experiments to stimulate the bacterial degradation of benzo(a)pyrene, a 5-ring PAH, were unsuccessful.

20A

Field Evaluation of In-Situ Biodegradation of Chlorinated Ethenes: Part 1, Methodology and Field Site Characterization, Journal Article: Published in *Ground Water*, v28n4, July/August 1990.
Hopkins, G.D.; Mackay, D.M.; and Roberts, P.V., et al, Stanford University, CA Department of Civil Engineering, Sponsored by Robert S. Kerr Environmental Research Laboratory, Ada, OK, July/August 1990

NTIS Document Number: PB91-144857/XAB

Careful site characterization and implementation of quantitative monitoring methods are prerequisites for a convincing evaluation of enhanced biostimulation for aquifer restoration. The paper describes the characterization of a site at Moffett Naval Air Station, Mountain View, California, and the implementation of a data acquisition system suitable for real-time monitoring of subsequent aquifer restoration experiments. A shallow, confined aquifer was chosen for the enhanced biodegradation demonstration, and was shown to have suitable hydraulic and geochemical characteristics. Injection and extraction wells were installed at a distance of 6 m, with intermediate monitoring wells at distances of 1, 2.2, and 4 meters from the injection well. Bromide tracer tests revealed travel times of 8 to 27 hours from the injection well to the various monitoring wells, and 20 to 42 hours from the injection well to the extraction well. Complete breakthrough of the tracer at the monitoring wells was facilitated by choosing a line of wells aligned with the regional flow, and selecting injection and extraction flow rates of approximately 1.5 and 10 liters/min. Transport studies were conducted with selected halogenated organic compounds. The retardation factors were found to range from approximately 2 to 12. The breakthrough responses for the more strongly sorbing compounds, e.g. TCE, exhibited pronounced tailing, such that a minimum period of several weeks was required to achieve complete saturation of the aquifer.

20B

Field Scale Investigation of Enhanced Petroleum Hydrocarbon Biodegradation in the Vadose Zone Combining Soil Venting as an Oxygen Source with Moisture and Nutrient Addition. (Appendices, Doctoral Thesis).
Miller, R.N., Air Force Institute of Technology, Wright-Patterson AFB, OH, 1990

NTIS Document Number: ADA227981/8/XAB

This document contains appendices regarding a reprint on a field scale investigation of enhanced petroleum hydrocarbon biodegradation in the Vadose zone combining soil venting as a oxygen source with moisture and nutrient addition.

20C

Fungal Degradation of Organophosphorous Insecticides.
Bumpus, J.A.; Coleman, R.D.; and Kakar, S.N., Argonne National Lab, IL, 1992

NTIS Document Number: DE92-016191/XAB

Organophosphorous insecticides are used extensively to treat a variety of pests and insects. Although as a group they are easily degraded by bacteria in the environment, a number of them have half-lives of several months. Little is known about their biodegradation by fungi. We have shown that Phanerochaete chrysosporium can substantially degrade chlorpyrifos, fonofos, and terbufos (27.5%, 12.2%, and 26.6%, respectively) during 18-day incubation in nitrogen-limited stationary cultures. The results demonstrate that the chlorinated pyridinyl ring of chlorpyrifos and the phenyl ring of fonofos undergo ring cleavage during biodegradation by the fungus. The usefulness of the fungus system for bioremediation is discussed.

20D

In-Situ Biodegradation of Nitroaromatic Compounds in Soil.
Crawford, R.L., Idaho University, Moscow Center for Hazardous Waste Remediation Research, Air Force Office of Scientific Research, Bolling AFB, Washington, DC, June 1992

NTIS Document Number: ADA254120/9/XAB

Investigations on the in-situ biodegradation of nitroaromatic compounds have progressed nicely. Laboratory studies have identified the primary intermediate compounds from anaerobic metabolism to be hydroxyaromatic compounds that are all biodegradable. Studies have identified the environmental parameters affecting the initial transformation of TNT and RDX in anaerobic cultures. Optimum pH and temperature for biodegradation is a pH of 8 and temperatures of 25-35 degrees C. Microbiological studies will continue to determine ways of enhancing the biodegradation of these compounds.

20E

In-Situ Biological Treatment Test at Kelly Air Force Base, Volume 2. Field Test Results and Cost Model, Report June 1, 1985 - May 31, 1987.
Davidson, D.H.; Durst, C.M.; and Wetzel, R.S., et al, Science Applications International Corporation, McLean,

VA, Air Force Engineering and Services Center, Engineering and Services Laboratory, Tyndall AFB, FL, July 1987

NTIS Document Number: ADA203213/4/XAB

The objective of this effort was to field test in-situ biodegradation to treat aquifer contaminants. In-situ biodegradation is enhanced by stimulating the indigenous subsurface microbial population by the addition of nutrients and an oxygen source to promote degradation of organic contaminants. In-situ treatment affects contaminants sorbed to soil as well as dissolved in groundwater. It is potentially faster, and therefore cheaper, than conventional pump-and-treat technologies. The test site, located at Kelly AFB, Texas, was contaminated with a mixture of organic and inorganic chemicals. The treatment system consisted of an array of nine pumping wells and four infiltration wells. These wells circulated groundwater and transported the treatment chemicals throughout the 2800 square feet treatment area. Oxygen was supplied by means of a hydrogen peroxide solution. Nutrients were principally ammonium and phosphate salts. The system was operated for nine months. Data showed evidence of both aerobic and anaerobic biodegradation. Decreases in tetrachloroethylene and trichloroethylene concentrations in groundwater correlate with anaerobic microcosm tests. Aerobic biodegradation was indicated by acid and carbon dioxide production and increases in petroleum hydrocarbon concentrations in groundwater.

21A

In-Situ Biorestoration of a Subsoil Contaminated with Gasoline, Interim Report.
Eikelboom, D.H.; Van den Berg, R.; and Verheul, J.H.A.M., Rijksinstituut voor de Volksgezondheid en Milieuhygiene, Bilthoven (Netherlands), Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, The Hague (Netherlands), April 1989

NTIS Document Number: PB90-247727/XAB

Report on the International Meeting of the NATO/CCMS Pilot Study (2nd) Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. The objective of the research project 'In-situ biorestoration of an oil-contaminated subsoil' is to study the technical and financial feasibility of this technique. In the report the results of the pilot plant scale column studies are given and discussed. Moreover, a description of the site and the design of the actual clean-up operation are given. In the undisturbed soil columns the gasoline was removed by two processes: leaching and (bio)degradation. By leaching predominantly the aromatic compounds were removed and especially in the first few weeks. Considerable (bio)degradation, besides leaching, was observed only in the cases of hydrogen peroxide used as additional oxygen source, recirculation of the effluent and a combination of these two. Both aromatic and especially aliphatic compounds were biodegraded.

21B

Installation Restoration Program. Environmental Technology Development Task Order 8. Field Demonstration- Composting of Explosives - Contaminated Sediments at the Louisiana Army Ammunition Plant (LAAP) Final Report June 1986 - September 1988.
Marks, P.J.; Williams, R.T.; and Ziegenfuss, P.S.; Weston (Roy F.) Inc., West Chester, PA, September 1988

NTIS Document Number: ADA202383/6/XAB

A field scale demonstration of composting explosives contaminated sediments was conducted at the Louisiana Army Ammunition Plant (LAAP) Composting, as used at LAAP, is a treatment process in which organic chemical-contaminated soils or sediments are mixed with organic materials such as manure to enhance the role of microbial metabolism in degrading and stabilizing soil/sediment contaminants. Lagoon sediments contaminated with TNT, HMX, RDX, and tetryl were mixed with manure, straw, hay, live-stock feed, and fertilizer and composted for 153 days in static piles. Negative pressure aeration was used to maintain aerobiosis and remove excess heat, The initial total explosives concentration in compost was approximately 17,000 mg/Kg (1.7 wt%). After 153 days of composting in a mesophilic (35C) and a thermophilic (55C) compost pile, the concentration of solvent-extractable total explosives in compost was reduced to 376 and 74 mg/Kg, respectively. Mean percent reductions for TNT, RDX, and HMX in the mesophilic pile were 99.6, 94.8 and 86.9 wt%, respectively. Corresponding values for the thermophilic piles were 99.9, 99.1, and 96.5 wt%. Known biotransformation products of TNT (diamino-nitrotoluenes and amino-dinitrotoluenes) were detected in the initial compost, increased in concentration during the first four weeks of composting, and decreased to low mg/Kg levels thereafter.

21C

Metabolism of Chlorinated Methanes, Ethanes, and Ethylenes by a Mixed Bacterial Culture Growing on Methane, Journal Article: Published in *Journal of Industrial Microbiology*, v4n1, January 1989.
Cochran, J.W.; Henson, J.M.; and Yates, M.V., RMT, Inc., Greenville, SC, Department of Soil and Environmental Sciences, California University, Riverside, Illinois Dept. of Energy and Natural Resources, Champaign, IL, Hazardous Waste Research and Information Center, Northrop Services, Inc., Ada, OK, Robert S. Kerr Environmental Research Lab, Ada, OK, 1989

EPA Document Number: R-812220

NTIS Document Number: PB91-144774/XAB

Soil was taken from the top 10 cm of a soil column that removed halogenated aliphatic hydrocarbons in the presence of natural gas. The soil was used as an enrichment inoculum to determine that the removals seen in the soil column were in fact of a microbiological nature. Methane served as the source of carbon and energy and was consumed immediately by the enrichments. After several transfers of the enrichments, a stable consortium of at least three bacterial types was obtained. The predominant bacterium was a non-motile, gram-negative coccus. The stable consortium was able to remove chlorinated methanes, ethanes, and ethylenes when grown with methane and oxygen in the headspace. Methane was required for the removals to be observed. Acetylene inhibited the removals, which further suggests the involvement of methanotrophs. Benzene and toluene were removed by the mixed culture, which further suggests the involvement of methanotrophs. Benzene and toluene were removed by the mixed culture with or without methane in the headspace. Fatty acid analysis of the mixed culture resulted in a profile that indicated that the predominant organism was a type II methanotroph. The study provides further evidence that methanotrophic bacteria are capable of cometabolizing a wide range of chlorinated methanes, ethanes, and ethylenes.

22A

Microbial Degradation of Toluene Under Sulfate-Reducing Conditions and the Influence of Iron on the Process.

Beller, H.R.; Grbic-Galic, D.; Reinhard, M., Department of Civil Engineering, Stanford University, CA, Robert S. Kerr Environmental Research Laboratory, Ada, OK, 1992

EPA Document Number: 600/J-92/139

NTIS Document Number: PB92-166735/XAB

Toluene degradation occurred concomitantly with sulfate reduction in anaerobic microcosms inoculated with contaminated subsurface soil from an aviation fuel storage facility near the Patuxent River (Md.). Similar results were obtained from enrichment cultures in which toluene was the sole carbon source. Several lines of evidence suggest that toluene degradation was directly coupled to sulfate reduction in Patuxent River microcosms and enrichment cultures: (1) the two processes were synchronous and highly correlated, (2) the observed stoichiometric ratios of moles of sulfate consumed per mole of toluene consumed were consistent with the theoretical ratio for the oxidation of toluene to CO_2 coupled with the reduction of sulfate to hydrogen sulfide, and (3) toluene degradation ceased when sulfate was depleted, and conversely, sulfate reduction ceased when toluene was depleted. Mineralization of toluene was confirmed in experiments with (ring-U-14C)toluene. The addition of millimolar concentrations of amorphous Fe(OH)3 to Patuxent River microcosms and enrichment cultures either greatly facilitated the onset of toluene degradation or accelerated the rate once degradation had begun. In iron-amended microcosms and enrichment cultures, ferric iron reduction proceeded concurrently with toluene degradation and sulfate reduction. Stoichiometric data and other observations indicate that ferric iron reduction was not directly coupled to toluene oxidation but was a secondary, presumably abiotic, reaction between ferric iron and biogenic hydrogen sulfide. (Copyright (c) 1992, American Society for Microbiology.)

22B

On-Site Treatment of Creosote and Pentachlorophenal Sludges and Contaminated Soil Research Report January 1988 - April 1990.

Borazjani, H.; McGinnis, G.D.; and Pope, D.F.; et al, Mississippi Forest Products Utilization Laboratory, Mississippi State, Robert. S. Kerr Environmental Research Laboratory, Ada, OK, May 1991

NTIS Document Number: PB91-223370/XAB

Information is presented for quantitative evaluation of treatment potential for creosote and pentachlorophenol (PCP) wood treating contaminants in soil systems. The study was conducted in three phases: (1) characterization; (2) treatability screening; and (3) field evaluation. Data generated in phases 1 and 2 were discussed in a previous EPA Report (EPA/600/2-88/055). The report provides review of data generated during phases 1 and 2 plus discussion of data generated during the two-year field evaluation study. Results from the three-phase study indicated that creosote contaminants, i.e., polycyclic aromatic hydrocarbon (PAH) compounds, and PCP are subject to degradation in the soil system; loading rates and previous exposure of site soil to particular contaminants were identified as important factors in determining rates of transformation for a particular site. Although populations of PAH- and PCP-acclimated organisms increased markedly when these compounds were applied to rest soils, no correlation was found between microbial population levels and transformation rates for specific compounds of concern. Migration of compounds column leaching studies were conducted.

22C

Preliminary Feasibility and Cost Analysis of In-Situ Microbial Filter Concept.

Carman, L.M.; Knapp, R.B.; Taylor, R.T.; and Wijensinghe, A.M., Lawrence Livermore National Laboratory, CA.,

Sponsored by the U.S. Department of Energy, Washington, DC, March 1992

EPA Document Number: A-812220

NTIS Document Number: DE92-018662/XAB

In this report the cost of installing and operating an in-situ microbial filter to remediate a site at which the groundwater is contaminated by TCE is estimated and compared against the cost of remediation by a standard pump and treat method. In this microbial filter method, relatively thin vertical filters are installed in the subsurface to intercept contaminant plumes that are being transported by the flowing groundwater. The filters are created by injecting into the subsurface methanotrophic microbes grown in surface bioreactors and allowing them to become attached to the soil. The microbes produce an enzyme (MMO) that fortuitously catalyzes the degradation of TCE into carbon dioxide, water, and chloride ions. Because no external energy or carbon source is provided, the microbes remain metabolically active only for a limited time so that the filter needs to be periodically replenished with fresh microbes. Two methods of establishing and maintaining the microbial filter using eight vertical or horizontal wells were studied. In the pump and treat method considered for comparison, the groundwater pumped to the surface is first subjected to air-stripping of the liquid-phase volatile organic compound (i.e., VOC) from the groundwater followed by adsorption of the heated vapor-phase VOC by granular activated carbon (i.e., GAC) within a packed-bed filter.

23A

Process and Economic Feasibility of Using Composting Technology to Treat Waste Nitrocellulose Fines, Final Report October 1989 - March 1991.
Breed, C.E.; Crim, M.C.; and McGill, K.E.; et al, Tennessee Valley Authority, Muscle Shoals, AL, March 1991

NTIS Document Number: ADA241033/0/XAB

An evaluation of the process and economic feasibility of using composting technology to dispose of waste nitrocellulose (NC) fines (slurried in water) from the Radford Army Ammunition Plant (RAAP), Radford, Virginia, was undertaken by the Tennessee Valley Authority (TVA). Two general categories of composting technology were evaluated: (1) static pile processing in which the NC fines are mixed with composting amendments and stacked in long aerated piles, and (2) in-vessel processing in which NC composting is carried out inside a process vessel and the compost mix is handled by mechanical processing equipment. For the static pile process evaluation, a detailed conceptual design was made to provide a basis for estimation of capital and operating costs. This design was then evaluated at two levels of waste NC fines throughput. For the in-vessel process evaluation, commercial and demonstration scale composting facilities were visited by TVA personnel to gather process and economic information. This information was then modified conceptually to reflect operation of the particular process with NC fines at a throughput of 6000 pounds per day. Results determined that both types of composting technology, static pile and in-vessel, are technically feasible methods of disposing waste NC in slurry form.

23B

Removal of Volatile Aliphatic Hydrocarbons in a Soil Bioreactor, Journal Article: Published in *International Journal of Air Pollution Control and Hazardous Waste Management*, v37n10, October 1987.
Kampbell, D.H.; Read, H.W.; and Wilson, J.T., et al, Robert S. Kerr Environmental Research Laboratory, Ada, OK, Johnson (S.C.) and Son, Inc., Racine, WI, Prepared in cooperation with Johnson (S.C.) and Son, Inc., Racine, WI, 1987

NTIS Document Number: PB88-180393/XAB

Soil removal of propane, isobutane, and n-butane from a waste air stream was evaluated in the laboratory and in a prototype soil bioreactor. Laboratory investigations indicated first-order kinetics and the potential to degrade light aliphatic hydrocarbons and trichlorethylene, a compound ordinarily resistant to aerobic biological treatment. The predicted behavior of the field system based on laboratory studies, agreed closely with the actual behavior of the field system. The prototype bioreactor reduced the hydrocarbon concentrations in the air by at least 90% with a residencd time of 15 minutes and a pressure drop of 85 cm of water. The bioreactor functioned well through a range of temperatures, 12C to 24C.

23C

Soil Bioventing Demonstration Project.
Cho, J.S.; Kampbell, D.H.; and Wilson, J.T.; et al, New Jersey Institute of Technology, Newark, NJ, Robert S. Kerr Environmental Research Laboratory, Ada, OK, Sponsored by Robert S. Kerr Environmental Research Laboratory, Ada, OK, 1990

NTIS Document Number: PB91-162628/XAB

A pilot scale demonstration project of a soil bioventing system, which utilizes the biodegradation in soil and physical removal of VOC by induced air flow, is in operation at the U.S. Coast Guard Aviation Field in Traverse City, Michigan. The system is being tested to determine its suitability for remediation of the vadose zone in conjunction with aquifer remediation at a site contaminated by an aviation gas spill. Several microcosm studies with soil obtained from the vertical profile of the

contaminated site showed rapid microbial decompositions of hydrocarbon fumes with NPK nutrient and moisture addition. Basic removal kinetics data were obtained from these experiments. Field pneumatic pump tests for soil-air characterization have been conducted. The soil-air permeability and pressure distributions under the air injection/withdrawal systems were obtained. On the basis of information from the laboratory and field tests, a conceptual design at a field scale was made. The system will be implemented on the selected study site and the operation will start in fall, 1990. Additional soil core samplings and continuous monitoring of operation are planned.

24A

TCE Removal from Contaminated Soil and Ground Water, Ground Water Issue.
Matthews, J.E.; Russell, H.H.; and Sewell, G.W., U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC, January 1992

EPA Document Number: 540/S-92/002

NTIS Document Number: PB92-224104/XAB

Trichloroethylene (TCE) is a halogenated aliphatic organic compound which, due to its unique properties and solvent effects, has been widely used as an ingredient in industrial cleaning solutions and as a universal degreasing agent. Methods that are required for remediation of water contaminated with TCE if such water is to be used for human consumption are discussed. The purpose of this paper is to: (1) present a synopsis of physicochemical properties and reactive mechanisms of TCE, and (2) delineate and discuss promising remediation technologies that have been proposed and or demonstrated for restoring TCE-contaminated subsurface environmental media.

24B

Treatment of Chlorophenol-Contaminated Water and Soils Using Immobilized Microorganisms, Final Report September 27, 1987 - March 29, 1989.
Chresand, T.J.; and Crawford, R.L., BioTrol, Chaska, MN, Geological Survey, Water Resources Division, Reston, VA, 1990

NTIS Document Number: PB90-222241/XAB

A pentachlorophenol (PCP)-degrading Flavobacterium, a p-cresol-degrading Pseudomonas, and the lignin-degrading P. chrysosporium were all effectively immobilized in both alginate and polyurethane. The immobilized cells effectively degraded their target compounds, and the systems proved amenable to use in batch or fluidized bed reactors for degrading PCP or cresol contaminated water and soil. Polyurethane appears to be the immobilization matrix of choice for field application. Electron microscopy showed that cells were likely entrapped in small pores in the foam as opposed to being covalently linked to it. A field laboratory was assembled at a wood treating site and a 40 liter fluidized bed reactor containing foam-immobilized Flavobacterium was operated for a four week trial. The system achieved approximately 75% removal of PCP with a residence time of 0.5 hours, and approximately 90% removal with a residence time of 0.8 hours.

24C

Treatment Potential for 56 EPA (Environmental Protection Agency) Listed Hazardous Chemicals in Soil, Final Report September 1, 1983 - February 28, 1987.
Doucette, W.J.; McLean, J.E.; and Sims, R.C., et al, Utah State Univ., Logan, UT, Department of Civil and Environmental Engineering, Robert S. Kerr Environmental Research Laboratory, Ada, OK, Sponsored by Robert S. Kerr Environmental Research Laboratory, Ada, OK, February 1988

EPA Document Number: R-810979

NTIS Document Number: PB88-174446/XAB

Information is presented for quantitative evaluation of soil treatment potential for 56 hazardous chemicals. The chemicals were organized into four categories: PAH, pesticides, chlorinated hydrocarbons, and miscellaneous chemicals. Treatability studies were conducted to determine: degradation rates, phase partition coefficients, and transformation characteristics. Results of soil fate/transport predictions of two mathematical models were compared with laboratory and literature results to evaluate ability of models to predict behavior of selected chemicals. Experimental approach used was designed to characterized degradation, immobilization, and transformation potentials for the hazardous substances. Results indicated that significance of volatilization and abiotic-loss processes in influencing 'apparent loss rates' of substances depended on class of substance. The processes were insignificant for majority of PAHs; biodegradation appears to be major process for PAH loss. Abiotic loss may also be important process for certain pesticides.

TEST DESIGNS/PROTOCOLS

24D

A Field Evaluation of In-Situ Biodegradation for Aquifer Restoration.
Hopkins, G.D.; Mackay, D.M.; Roberts, P.V.; Semprini, L., and U.S. Department of Civil Engineering, Stanford University, Stanford, CA, Sponsored by Robert S. Kerr Environmental Research Laboratory, Ada, OK, U.S. Environmental Protection Agency, Ada, OK, November 1987

EPA Document Number: 600/15

NTIS Document Number: PB88-130257/AS

The in-situ remediation of aquifers contaminated with halogenated aliphatic compounds is a promising alternative in efforts to protect groundwater. This report presents the experimental methodology and the initial results of a field experiment evaluating the feasibility of in-situ biotransformation of TCE and related compounds. The method being tested relies on the ability of methane oxidizing bacteria to degrade these contaminants to stable end products. The test zone is a shallow, confined aquifer located at the Moffett Naval Air Station, Mountain View, California.

25A

Biological Remediation of Contaminated Soils at Los Angeles Air Force Base: Facility Design and Engineering Cost Estimate.

Irvine R.L. and Montemagno, C.D., Argonne National Laboratory, IL, Environmental Assessment and Information Sciences Division, Sponsored by the U.S. Department of Energy, Washington, DC, August 1990

NTIS Document Number: DE91-006975/LL

This report presents a system design for using bioremediation to treat contaminated soil at Fort MacArthur near Los Angeles, California. The soil was contaminated by petroleum products that leaked from two underground storage tanks. Laboratory studies indicated that, with the addition of water and nutrients, soil bacteria can reduce the petroleum content of the soils to levels that meet regulatory standards. The system design includes soil excavation, screening, and mixing; treatment in five soil-slurry/sequencing-batch reactors; and dewatering by a rapid-infiltration basin. System specifications and cost estimates are provided. 5 refs., 8 figs., 5 tabs.

25B

In-Situ Bioremediation of Contaminated Groundwater.

Russell, H.H.; Sims, J.L.; and Suflita, J.M., U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC, February 1992.

EPA Document Number: 540/5-92/003

NTIS Document Number: PB92-224336/XAB

In-situ bioremediation, where applicable, appears to be a potential cost-effective and environmentally acceptable remediation technology. Suflita (1989) identified characteristics of the ideal candidate site for successful implementation of in-situ bioremediation. These characteristics included: (1) a homogeneous and permeable aquifer; (2) a contaminant originating from a single source; (3) a low ground-water gradient; (4) no free product; (5) no soil contamination; and (6) an easily degraded, extracted, or immobilized contaminant. Obviously, few sites meet these characteristics. However, development of information concerning site specific geological and microbiological characteristics of the aquifer, combined with knowledge concerning potential chemical, physical, and biochemical fate of the wastes present, can be used to develop a bioremediation strategy for a less-than-ideal site.

25C

Microbial Decomposition of Chlorinated Aromatic Compounds

Blackburn, J.W. and Rochkind, M.L., IT Corporation, Knoxville, TN; Sayler, G.S., The University of TN, Knoxville, TN; Alternative Technologies Division, Hazardous Waste Engineering Research Laboratory, Office of Research and Development, Cincinnati, OH, September 1986

EPA Document Number: 600/2-86/090

NTIS Document Number: PB87-116943/LL

This report is a compendium describing the current level of understanding of chlorinated aromatic compound decomposition by microbiological pathways. The halogenated aromatic compounds are one of the most persistent collections of chemicals contaminating the environment. The persistent nature of these chemicals is attributable to the inability of the environment to cleanse itself of these contaminants. Since microbiological communities are fundamental participants in the detoxification chain, the environment generally does not have microorganisms capable of degrading the halogenated aromatic compounds. This report specifically identifies microorganisms capable of degrading many of the halogenated organic species. In many cases, the substrate is tracked through a decomposition pathway to end product. Many factors contribute to the biodecomposition of a given chemical; among the most important are: the chemical nature of the substrate molecule and substituents, substrate concentration, environmental parameters, nutrients and growth factor availability, and the presence of organisms capable of degrading the substrate.

25D

Treatability and Scale-Up Protocols for Polynuclear Aromatic Hydrocarbon Bioremediation of Manufactured Gas Plant Soils. Final Report, September 1987 - July 1991.

Blackburn, J.W.; Digrazia, P. M.; and Sandeverino, J., Tennessee University, Knoxville, TN, Gas Research Institute, Chicago, IL, 1991

NTIS Document Number: PB91-240713/XAB

The report describes activities to develop a framework to reliably scale-up and apply challenging bioremediation processes to polynuclear aromatic hydrocarbons in Manufactured Gas Plant (MGP) soils. It includes: a discussion of the accuracy needed for competitive application of bioremediation; a framework and examples for treatability and scale-up protocols for selection, design and application of these processes; both batch and continuous testing protocols for developing predictive rate data; and special predictive relationships that may be used in process selection/scale-up. The work, coupled with subsequent work (as recommended) to develop an MGP soil desorption/diffusion protocol and new scale-up methods, and with subsequent scale-up testing should lead to the capability for improved selection of MGP sites for bioremediation and improved performance, success, and reliability of field applications. With this greater predictive reliability, bioremediation will be used more often in the field on the most favorable applications and its cost advantages over other remediation options will be realized.

EXAMPLES OF OTHER RELEVANT DOCUMENTS

26A

Biodegradation of Volatile Organic Chemicals in a Biofilter: Published in *American Chemical Society Symposium Series 468 "Emerging Technologies in Hazardous Waste Management II."*

Brenner, R.C.; Govind, R.; Safferman, S.; Shan, Y.; Utgikar, V., Department of Chemical Engineering, University of Cincinnati, Cincinnati, OH, Risk Reduction Engineering Laboratory, U.S. Environmental Protection Agency, Cincinnati, OH, 1991

Access Relevant ACS Symposium Series at Library

Emission of the volatile organic compounds (VOCs) has recently received increased attention due to its environmental impact. It is possible to treat these compounds by biodegradation. A mathematical model has been developed in this paper to describe the biodegradation of the VOCs in a biofilter. Numerical solutions of a mathematical model describing the steady state biodegradation of VOCs in the biofilter have been presented in the paper. The use of the model in design of the biofilter is demonstrated for a given load of leachates. Preliminary experimental data on the removal of toluene and methylene chloride have been presented. Calculations have been made for removal of the most common constituents of the leachate. It was found that for an inlet gas flow rate of 0.175 m^3/s(370 ft^3/min), a biofilter 3m in diameter and 5.3 m in height is required for 90% removal of the contaminants.

26B

Treatment of CERCLA Leachates by Carbon-Assisted Anaerobic Fluidized Beds, Journal Article: Published in *Water Science Technology*, v27n2, 1993.

Brenner, R.C.; Krishnan, E.R.; Nath, R.; Schroeder, A.T.; and Suidan, M.T., Department of Civil and Environmental Engineering, University of Cincinnati, Cincinnati, OH, ITEP Inc., Cincinnati, OH, U.S. Environmental Protection Agency, Cincinnati, OH, 1993

Access Relevant Journal at Library

Two anaerobic granular activated carbon (GAC) expanded-bed bioreactors were tested as pretreatment units for the decontamination of hazardous leachates containing volatile and semivolatile synthetic organic chemicals (SOCs). The different characteristics of the two leachate feed streams resulted in one reactor operating in a sulfate-reducing mode and the second in a strictly methanogenic environment. Both reactors were operated with a 6-hour unexpanded empty-bed contact time and achieved SOC removal acceptable for pretreatment units. In both reactors, the majority of the SOCs were removed by biological activity, with GAC adsorption providing stability to each system by buffering against load fluctuations.

26C

Treatment of VOCs in High Strength Wastes Using an Anaerobic Expanded-Bed GAC Reactor, Journal Article: Published in *Water Research*, v27n1, 1993.

Brenner, R.C.; Gelderloos, A.B.; Narayanan, B.; Suidan, M.T., John Carollo Engineers, Walnut Creek, CA, Department of Civil and Environmental Engineering, University of Cincinnati, Cincinnati, OH, Malcom Pirnie Inc., Newport News, VA, Risk Reduction Engineering Laboratory, U.S. Environmental Protection Agency, Cincinnati, OH, 1993

Access Relevant Journal at Library

The potential of the expanded-bed granular activated carbon (GAC) anaerobic reactor in treating a high strength waste containing RCRA volatile organic compounds (VOCs) was studied. A total of six VOCs, methylene chloride, chlorobenzene, carbon tetrachloride, chloroform, toluene and tetrachloroethylene, were fed to the reactor in a high strength matrix of background solvents. Performance was evaluated. The reactor was found to effect excellent removal of all VOCs (97%). Chloroform, while itself removed at levels in excess of 97%, was found to inhibit the degradation of acetate and acetone, two of the background solvents. Without any source of chloroform in the feed, excellent COD removals were obtained in addition to near-complete removal of all the VOCs.

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